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The ecological condition of the Gulf of Finland: microbiological and phytoplanktonic intercalibrations and a review of macrophyte investigations.

The Biological Section of the Soviet-Finnish Working Group on the Gulf of Finland.

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THE ECOLOGICAL CONDITION OF THE GULF OF FINLAND: MICROBIOLOGICAL AND PHYTOPLANKTONIC INTERCALIBRATIONS AND A REVIEW OF MACROPHYTE INVESTIGATIONS

INTRODUCTION AND SUMMARY

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(Members of the Biological Section of the Soviet-Finnish Working Group on the Gulf of Finland)

BACKGROUND

Bilateral cooperation between the Soviet Union and Finland concerning protection of the Gulf of Finland was established in 1968 within the framework of the joint Scientific-Technological Committee. In the early seventies a number of sections were set up to establish discussions on topics related to the main problem areas dealt with by the Working Group on the Gulf of Finland. The task of the Biological Section of the Working Group was to assess the ecological conditions of the Gulf of Finland on the basis of biological determinants. In order to make it possible to carry out the overall task given to the section, comprehensive basic work first had to be done. This included intercalibrations of methods used in the different participating laboratories, and discussions on taxonomic problems. The necessity for intercalibration of several biological determinants appeared already at the beginning of the work. The results of the first intercalibration exercise, held on board the

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Finnish research vessel Aranda, were published in 1980 (Järvekülg et al.).

The activities of the Biological Section were markedly intensified and the tasks of the Section broadened following the biological symposium held in Tallinn in 1973. In 1974 a report on macrozoobenthos as an indicator of the state of the Gulf of Finland was presented by Järvekülg, and a corresponding report on phytoplankton determinants by Lassig et al. (1974). In 1981 a symposium on "Problems Concerning Bioindication of the Ecological Condition of the Gulf of Finland" was arranged in Pärnu in the Estonian SSR. The proceedings of the symposium were published in a special volume of Hydrobiological Researches (Trei 1985).

The papers included in the present volume have been prepared according to the work plan of the Biological Section. This article summarises the main results presented in the subsequent papers of this volume.

NEW RESULTS

The first Finnish-Soviet intercalibration of the microbiological determinants (Järvekülg et al. 1980) showed that the results obtained by the different laboratories were not directly comparable due to the use of different methods and culture media. As a results, Difco plate agar and the Soviet nutrient agar used for enumeration of saprophytes were compared and the effect of NaCl supplement in the media and dilution water was studied (before the next intercalibration). GELMAN and SYNPOR membrane filters, used for the recovery of coliform bacteria from brackish-water, were also compared. The new results presented by Saava and Rinne (1987a, b) showed that the Difco plate count agar gave a higher colony count than the Soviet standard. NaCl supplement in the dilution water had a significant effect on the colony counts of saprophytes in brackish-water, but the effect was negligible in the case of nutrient media. The GELMAN and SYNPOR membrane filters differed in their capacity to recover coli-bacteria. The second Finnish-Soviet intercalibration of saprophytes showed that comparable data can only be obtained when the same medium and procedures are used.

The phytoplankton intercalibrations carried out in 1978 (Järvekülg et al. 1980) showed that there is a certain degree of comparability in the quantitative results. In contrast, the fundamental problems arose in connection with species identification and a different understanding of taxonomy and nomenclature, chiefly due to different research traditions. These problems are also evident in the taxonomic works published by different plankton laboratories working around the Baltic Sea. In order to help resolve this situation, a new intercalibration was performed between Soviet and Finnish laboratories concentrating on species identification and taxonomy. The results (Kukk & Niemi 1987) specify those systematic groups of algae which should be treated in more detail: a seminar on phytoplankton taxonomy planned to be held in 1987 will be of profound interest.

Macrophytes in the Gulf of Finland have been studied for more than a century. Both in the USSR and Finland, the results of such studies have mostly been published as short papers in different journals, which are sometimes difficult to find. As the Finnish and Soviet scientists represent different research traditions, the Biological Section found it appropriate to compile and review earlier results in two different papers (Trei et al. 1987 and Hällfors et al. 1987). The bibliographies of the macrophyte studies carried out in the Gulf of Finland have been made as complete as possible.

Joint research of this kind, the intercalibrations, the reviews on investigations and assessments are activities essential if we are to gain a profound understanding and achieve protection of the Gulf of Finland. These activities will also be of great interest for the Baltic Sea research and for the aims of the Helsinki Commission.

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FINNISH-SOVIET INTERCALIBRATION OF PHYTOPLANKTON IDENTIFICATION USED FOR MONITORING THE CONDITIONS OF THE GULF OF FINLAND

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Other participants in the intercalibration:
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ABSTRACT

Species identification was performed on brackish-water phytoplankton samples taken during the vernal bloom and in late summer in order to intercalibrate the results obtained in Finnish and Soviet laboratories. There was a good agreement as regards common, abundantly occurring species. However, there was disagreement with respect to several algal groups. The reasons for this are discussed. Taxonomic notes on critical groups are given. Recommendations for further standardization work are presented.

1. GENERAL

A joint Finnish-Soviet intercalibration exercise on biological parameters was started in 1978 within the framework of the bilateral cooperation on the study of pollution in the Gulf of Finland between

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Finland and the Soviet Union. The intercalibration results for the determination of phytoplankton biomass, chlorophyll a, macrozoobenthos, mesophilic aerobic bacteria, coliform bacteria and enterococcs have been reported earlier (Järvekülg et al. 1980 in Meri 8).

The main target of the present intercalibration was the species identification of phytoplankton. There are great differences in the results of phytoplankton identification carried out by different laboratories, as has earlier been shown in international intercalibration exercises (Hobro & Willén 1975, 1977, Biological Workshop in Stralsund 1979, Barinova et al. 1980, Second Biological Intercalibration Workshop in Rönne, 1982, Baltic Marine Environment Protection Commission 1980 and 1983). The intercalibrations carried out so far have shown that the comparability of the counting itself is less of a problem than the identification of the species in question (Niemi et al. 1985).

An essential step towards the standardization of phytoplankton identification is the publishing of modern check lists (Hällfors 1979, Edler et al. 1984). Intercalibrating the phytoplankton species identification between the Finnish and Soviet laboratories concerned was considered to be an important part of the joint studies.

The following laboratories and researchers took part in the phytoplankton intercalibration study:

Helsinki City Water Laboratory, Helsinki (Maija Huttunen and Hilkka Viljamaa),
Finnish Institute of Marine Research, Helsinki (Mikaela Forsskåhl and Kaisa Kononen),
Institute of Radiation Protection, Helsinki (Jorma Keskitalo),
Institute of Zoology and Botany, Academy of Sciences of the Esthonian SSR, Tartu, (Kai Piirsoo),
National Board of Waters and Environment, Finland, Helsinki (Liisa Lepistö),
Tvärminne Zoological Station, University of Helsinki (Guy Hällfors, Seija Hällfors and Åke Niemi).

2. SAMPLING, MATERIAL AND METHODS

Material was collected on 2.5.1980, 23.4.1982, 21.7.1982 and 31.8.1982 at Tvärminne Storfjärd (St. XII) 59°51'N; 23°16'E in the outer archipelago zone at the entrance to the Gulf of Finland. Salinity and temperature values for the sampling periods are given in Table 1.

TABLE 1. Temperature and salinity of the trophogenic layer at Tvärminne Storfjärd (St. XII) (unpublished data of the Finnish Institute of Marine Research, Helsinki).

		1.5.80	21.4.82	21.7.82	1.9.82
T°C	0 m	5.5	2.2	18.1	13.3
	5 m	4.9	2.2	16.5	13.4
	10 m	4.5	1.4	14.6	10.1
S °/oo	0 m	4.88	5.85	6.10	6.42
	5 m	4.92	6.02	6.02	6.43
	10 m	4.94	6.48	6.12	6.55

In general, the phytoplankton composition at Tvärminne Storfjärd does not essentially differ from that in the open Gulf of Finland. However, when the sea level is sinking and the surface outflow from the inlet Pojoviken is strong, the size of the freshwater element may occasionally be marked (Niemi 1973, 1975, Hällfors et al. 1983).

Two samplings (2.5.1980, 23.4.1982) represent the vernal bloom of cold-water diatoms and dinoflagellates. Two samplings (21.7.1982, 31.8.1982) represent the late summer phytoplankton including several systematic groups, especially blue-green algae. The outflow from Pojoviken was not marked during all four samplings.

The phytoplankton material was collected with a phytoplankton net (20 µm). The net was hauled horizontally at depths of 4 to 0 m. The phytoplankton material was collected in 2 two-litre bottles. The material in one bottle was fixed with formalin, the other with Lugol + acetic acid. Subsamples of the well-mixed material were sent to participating laboratories for analysis of the species composition.

The abundance of identified species is reported as follows:

5 very abundant, dominant in the sample
4 abundant
3 moderate abundance, common in the sample
2 quite sparse, not many observations
1 very sparse, few observations
+ one or two observations

Some of the laboratories also studied the material using diatom slides. Observations from diatom slides are designated with ^{o} in the tables (Appendix). In one of the laboratories 2 persons analysed the material independently. The observations of the second person are given in parentheses. The designation cf or ? is given by the laboratory and concerns the identification, not the abundance. If the abundance is given, for instance, as 3 - 5, it means that the abundance has been estimated in different replications by studying a number of microscopical subsamples or has been estimated separately by several researchers.

The results of the species identification analyses are presented in the tables in the Appendix.

3. COMMENTS ON THE PHYTOPLANKTON MATERIAL REPORTED BY PARTICIPATING LABORATORIES

One laboratory reported that the phytoplankton material had been partly destroyed. The samples stored at Tvärminne Zoological Station were re-examined in December 1983 and the formalin material was found to be still satisfactory for species identification. Some of the subsamples have probably been stored in unsuitable conditions for too long before the analyses.

According to information given by the participants, the participating laboratories stored their subsamples for different periods of time before the analyses. This, of course, may influence the quality of the material. The samples fixed in Lugol, in particular, should not be stored for too long a time and may have thus been partly destroyed. One laboratory found that the diatoms had been preserved better in Lugol than in formalin.

4. GENERAL COMMENTS ON THE INTERCALIBRATION RESULTS

There is excellent agreement in the species identification on common dominant species which are easy to fix and preserve. The estimations of their abundance also show good agreement (see Appendix).

The total number of reported taxa varies considerably between the laboratories. When additional diatom slides were studied, the number of taxa increased markedly. The same holds true for the more detailed analysis of the blue-green algae. All laboratories reported different results for occasionally occurring species in the material.

Quite abundantly occurring taxa have been overlooked or they are not known by some of the laboratories; the chrysomonads *Pedinella* and *Pseudopedinella*, the prymnesiophycean genus *Chrysochromulina*, the diatoms *Thalassiosira bramaputrae*, *T. levanderi* and *Chaetoceros septentrionalis* and *C. subtilis*, and the prasinophycean genera *Pyramimonas*, *Pedinomonas* and *Pseudoscourfieldia*. This may also depend on the analysis intensity.

The groups or taxa listed below are those which, according to the intercalibration results, were associated with difficulties in species identification.

Thin cyanophycean trichomes: *Achroonema* spp., *Oscillatoria limnetica*, *Lyngbya limnetica*

- *Anabaena*, especially *A. lemmermannii* and *A. spiroides*
- *Gomphosphaeria* and *Coelosphaerium*

- *Glenodinium* species, in general
- *Dinophysis acuminata* and *D. baltica*
- *Nitzschia closterium* and *N. longissima*
- *Surirella ovalis* and *S. ovata*
- *Amphiprora alata* and *A. paludosa*
- *Oocystis lacustris, O. borgei, O. submarina*

Distinguishing between *Cryptomonas* and *Rhodomonas* is difficult in fixed material. The same is valid for naked chrysomonads, prymnesiophyceans and euglenomonads. Small (< 10 µm) centric diatoms are usually impossible to identify on the species level in an Utermöhl-chamber. This is also the case with most of the naviculoid diatoms, e.g. *Gyrosigma*. Dinoflagellate-protoplasts are also named in different ways. The same is valid for naviculoid diatoms.

Some laboratories have reported finding *Chaetoceros borealis* and *Thalassiosira nordenskiöldii*, which are species that probably do not occur in the Northern Baltic Sea (Edler et al. 1984). See the tables in the Appendix for details of the intercalibration results.

5. NOTES ON TAXONOMY, IDENTIFICATION PROBLEMS AND OCCURRENCE OF THE BALTIC SEA PHYTOPLANKTON

Achroonema - Oscillatoria limnetica and *Lyngbya limnetica*

Achroonema is colourless and can only be observed in a light field microscope, not in phase contrast. In general, all the descriptions concerning algal species identification in older books are based on their colour and use pictures drawn from samples viewed in a light field microscope. In the intercalibration the described algae were studied using living material or material fixed in formalin etc. The colour of an alga is drastically altered in Lugol's solution, and thus in many algal groups it is difficult to determine the original colour. *Achroonema* spp. usually grow upon the bottom sediments, although near the coast they are occasionally abundant in the pelagial. They probably do not belong to the open sea plankton.

Oscillatoria limnetica (= *Pseudanabaena limnetica* (Lemm.) Komárek); cell width 1.5 µm and length 2.5 - 8x the width. They are strongly constricted at the cross-walls. *Achroonema lentum* is similar but colourless. *A. profundum* (Kirchner) Skuja 1956 (= *Oscillatoria profunda* Kirchner) is closely related to *A. lentum*. *A. profundum* is not constricted at the cross-walls and the cell length is 1 - 3x the width. *Achroonema simplex* Skuja 1956: the cell width is 1.8 - 2 µm, the length 3/4 - 1.5x the width and slightly constricted at the cross-walls. *Achroonema angustum* (Koppe) Skuja 1956 (= *Oscillatoria angusta* Koppe 1924) has long cells, a width of 0.7 - 1.2 µm, and the cross-walls are difficult to observe. *Oscillatoria limnetica* f. *brevis* Nygaard 1949 and *O. limnetica* var. *acicularis* Nygaard 1949 are somewhat similar algae, but in both taxa the trichoms apparently narrow toward the apex. They can be confused with *Raphidiopsis mediterranea* (this species has akinetes). Several undescribed *Achroonema* species occur in the archipelago waters of southern Finland (Prof. Heinrichs Skuja, personal communication at Tvärminne Zoological Station 1968).

Lyngbya limnetica trichoms are surrounded by a firm sheath that is longer than the trichom. Several filaments must be studied before the sheath can be observed with any certainty. There is a small volutin granula next to the cross-wall.

Pankow's (1976) Algal Flora of the Baltic Sea cannot be used for successful identification of *Anabaena* species. Pankow includes *A. lemmermannii* P. Richt. in *A. flos-aquae* (Lyngbye) Breb. (so also L. Geitler 1932), but A. Elenkin (1936:736) was of the opinion that *A. lemmermannii* differs from *A. flos-aquae* in two characteristics (also Niemi and Hällfors 1974): 1) Many coils develop from the center of the skein, viz. the end of the trichom turns back against the center of the skein. 2) The akinetes always develop in a cluster in the center of the skein, next to a heterocyst. The akinete cluster persists in the plankton for a long time after the trichoms have disappeared. *A. flos-aquae* does not apparently occur at all in the open Baltic Sea (Niemi and Hällfors 1974, Edler et al. 1984).

The somewhat similar species *Anabaena spiroides* Klebahn (sensu Pankow 1965) includes f. *hassalii* (= *Anabaena hassalii*

(Kütz.) Wittr.) and the synonym *Anabaena circinalis* Rabenhorst. This species was described already by Hansgirg (1892:68) and A. Elenkin (1938:740). The species *A. spiroides* Kleb., *A. hassalii* (Kütz.) Wittr. and *A. circinalis* Rabenh. can be regarded as comprising the following different species.

Anabaena circinalis (Kütz.) Hansg. The filaments are curved or S-shaped, usually solitary. Cells are roundedly cylindrical, width 2.5 - 5 µm, length 1.5 - 3x width, heterocysts 4-5 x 5-8 µm elongate, akinete solitary, cylindrical, curved, width 6 µm, length 24 - 30 µm, separated from the heterocyst (not next to a heterocyst).

Anabaena hassalii (Kütz.) Wittr. Filaments irregularly curved, not spirally twisted, often in a thick mucilage. Cells spherical or barrel-shaped, width 8 - 14 µm, heterocysts ± spherical, width 8 - 10 µm. Akinetes straight or curved, width 16 - 18 µm, length 30 - 34 µm, sometimes the inner side straight but the outer side curved, the ends tapering.

Anabaena spiroides Kleb. Filaments spirally twisted, diameter of spirals usually 45 - 54 µm, distance between spirals 40 - 50 µm. The cells spherical or shorter than their width, which is 6.5 - 8 (- 14) µm. The heterocysts almost spherical, 7 (-17) µm. Young akinetes spherical 18 µm, later on cylindrical, width 25 µm, length 42 µm.

Already Hansgirg (1892:68), Lemmermann (1910:186) and L. Geitler (1925:324) were against combining the species *A. circinalis, A. hassalii* and *A. spiralis*. It is highly unlikely that these freshwater species occur in the open Baltic Sea. The same is valid for *A. variabilis*, which occurs in archipelago waters (Hällfors 1979).

Anabaena baltica Schmidt appears to be a real brackish-water species (solitary filaments and smaller cell width (3 - 4 µm) than *A. lemmermannii*). This species has often been confused with *A. lemmermannii*, which is much more frequent in the Baltic proper and the Gulf of Finland (Niemi and Hällfors 1974).

Gomphosphaeria - Coelosphaerium

The *Coelosphaerium* cells are spherical. The *Gomphosphaeria* cells are elongated, often pear- or egg-shaped. Confusion is probably caused by a picture describing *Coelosphaerium roseum* Snow 1902 = *Gomphosphaeria rosea* (Snow) Lemmermann 1910 = *Snowella rosea* (Snow) Elenkin 1938:279, but published under the name *Gomphosphaeria lacustris* (in Smith 1920:36, Table 16, Fig. 5; Geitler 1925:99, Fig. 114; Geitler 1932:244, Fig 118a; Elenkin 1936:69, Fig. 29d; Prescott 1973 Pl. 106, Fig. 9; Järnefelt et al. 1963, Pl. 2, Fig. 8), although Chodat (1898:180) in his first description of *G. lacustris* mentions that the cells are obovoid. The colony in the preparation should be rotated because the eggs look spherical when viewed from a certain direction.

Dinophysis acuminata and *D. baltica*

According to Kiselev (1950) the following characteristics will separate the species. The small areoles in the anterior end of the hypotheca of *D. baltica* are smaller than those in *D. acuminata*. The chromatophores are brown and the vertical cell sides are almost straight. In *D. acuminata* the large areoles contain small poroits. The posterior end of the hypotheca often bears processes. The chromatophores are yellow. Fig. 694 in Pankow (1976) is not *D. acuminata*. According to Edler et al. (1984), *D. baltica* requires taxonomic re-investigation.

Surirella ovalis and *S. ovata*

S. ovalis has 16 striae/10 µm. The cell length is 20 - 100 µm, width 10 - 40 µm, rhombic. Occurs in brackish-water. *S. ovata has* 16 -20 striae/10 µm. The cell length is 15 - 70 µm, width 8 - 23 µm. The cell is egg-shaped. The species occurs in freshwater except for v. *salina* (W.Sm.) Hust., which is quite different: one apex is rounded, the other one cuneate. According to Edler et al. (1984), the Baltic material requires a taxonomic re-investigation. According to Guy Hällfors, Tvärminne Zoological Station (personal communication), intermediate types are also common in the archipelago waters of southern Finland.

Oocystis species

O. submarina Lagerh., *O. lacustris* Chodat, *O.borgei* Snow, *O. pelagica* Lemm. have been reported under different names. Reháková (1969) considered *O. pelagica* to be a synonym of *O. lacustris* Chodat 1897, and *O. borgei* as a synonym of *O. marssonii* Lemmermann 1898. The following characteristics should be examined in order to separate the species.

The cells of *O. submarina* are cylindrical and contain one or two discus-shaped or stelliform chloroplasts with a pyrenoid. The cells of *O. lacustris* are oval, and the ends are sharp and bear a point. The chloroplasts are plate-shaped. The cell ends of *O. borgei* are rounded, the cells oval. (1) - 2 - 4 lateral chloroplasts contain a pyrenoid. One colony may even include 3 generations. The cells of *O. marssonii* have 1 - 2 chloroplasts and acuminate ends without a noddle. The cells of *O. pelagica* are oval with rounded ends and contain several discus-shaped chloroplasts lacking pyrenoids.

6. CONCLUSIONS AND RECOMMENDATIONS

There was good agreement in the intercalibration results concerning the identification of common dominant species which are easy to fix and preserve. The results of the semiquantitative estimates were also in good agreement.

Apparent differences were found in the identification of nanoflagellates that are temporarily dominant in Baltic Sea phytoplankton, such as the groups Chrysophyceae, Prymnesiophyceae and Prasinophyceae. Moreover, identification problems arose with algae belonging to most of the algal classes. Much of the identification problems were due to badly fixed material. Differences in the knowledge of Baltic Sea phytoplankton was also apparent between the laboratories.

Certain algal groups, e.g. naked dinoflagellates, need extensive systematic research.

Phytoplankton should be studied alive, if possible. Fixation using Lugol's solution with acetic acid seems to be the best (Hällfors et al. 1979). The samples should not be stored (dark and cool) for more than a few months. Samples which cannot be studied within a few months should not be collected in large quantities.

This and other intercalibrations have shown (Niemi et al. 1985) that a uniform way of presenting the results is needed. In the case of doubtful species identification, the lowest level should be given. A way of indicating uncertainty should also be agreed upon and standardized (e.g. parentheses and ? or "").

Drawings and photos should be prepared and also published if possible. Attention should also be paid to the appearance of an alga when fixed.

Improving and updating the existing check-list (Edler et al. 1984) is a matter of great urgency, as also is the work on phytoplankton sheets for the Baltic Sea, which is supported by the Helsinki Commission.

Systematics is of basic importance if a satisfactory level is to be achieved in species identification. More frequent cooperation between planktologists and algologists working on Baltic Sea phytoplankton is desired. Workshops on a bilateral basis should be arranged.

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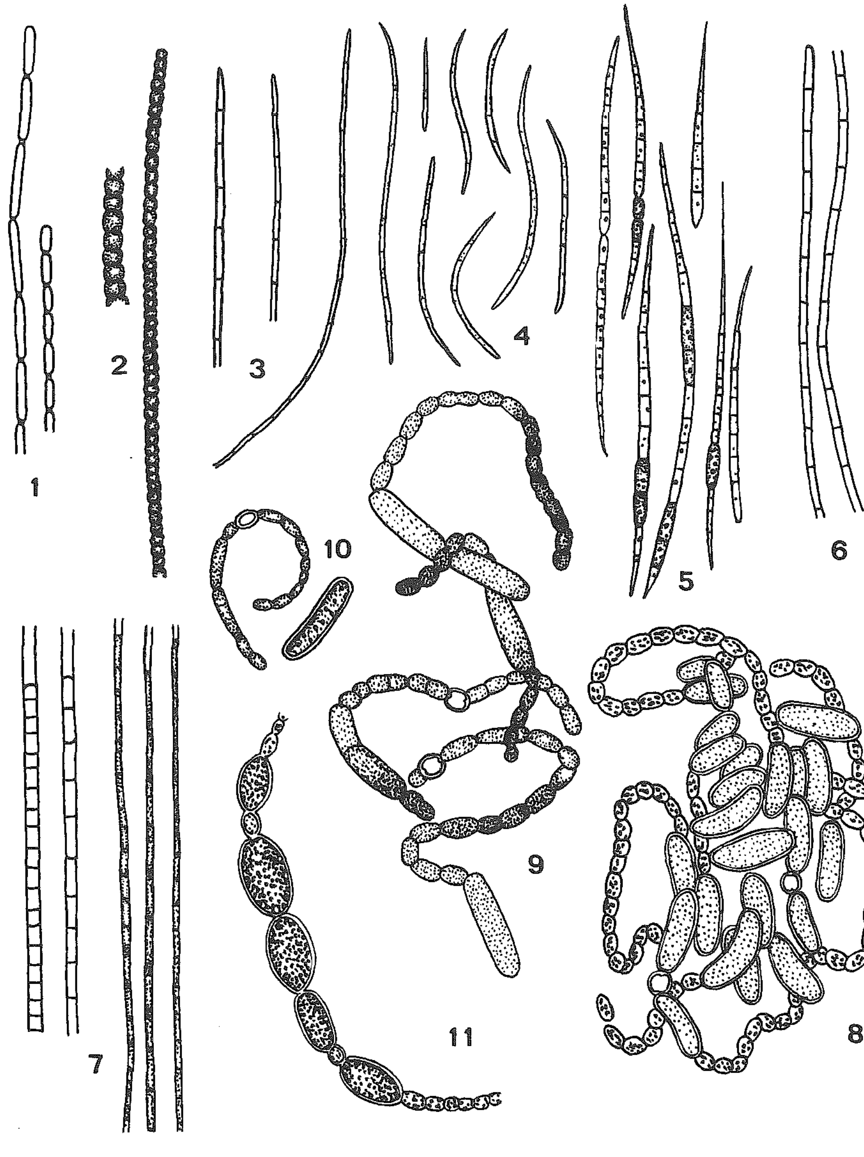

Plate 1.

Species:
1. Oscillatoria limnetica (redrawn after Nygaard)
2. Achroonema simplex (after Skuja)
3. Oscillatoria limnetica var. acicularis (a. Nygaard)
4. f. brevis (a. Nygaard)
5. Raphidiopsis mediterranea (a. Skuja)
6. Oscillatoria augusta (a. Komárek)
7. Lyngbya limnetica (after Geitler and Smith)
8. Anabaena lemmermannii (a. Kossinskaja)
9. A. flos-aquae (a. Smith)
10. A. circinalis (a. Lemmermann)
11. A. baltica (ex Huber-Pestalozzi after J. Schmidt)

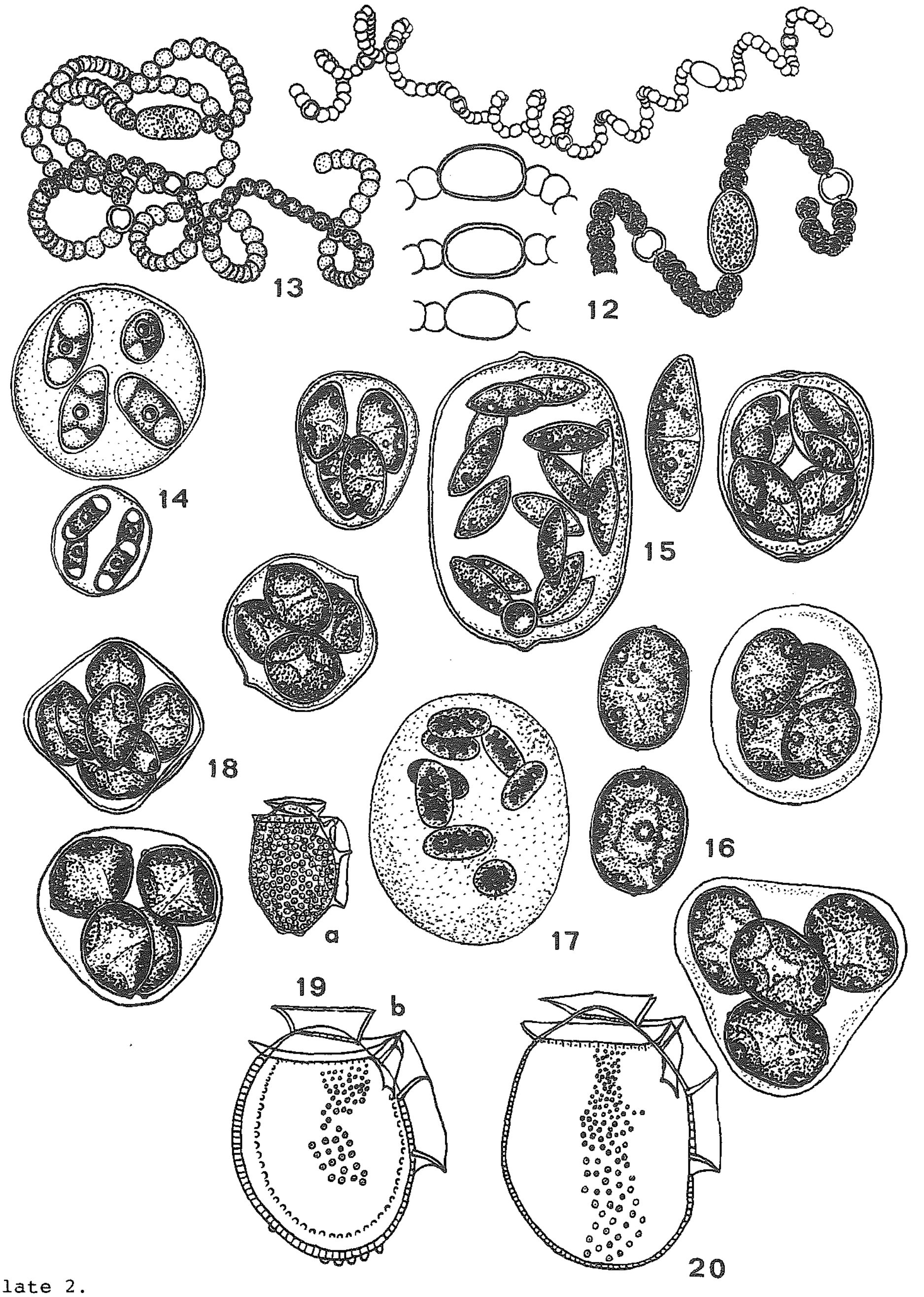

Plate 2.

Species:

12. Anabaena spiroides (a. Komárek)
13. A. hassalii (a. Smith)
14. Oocystis submarina (a. Hortobágyi)
15. O. lacustris (a. Skuja)
16. O. borgei (a. Skuja)
17. O. pelagica (a. Kol)
18. O. marssonii (a. Skuja)
19. Dinophysis acuminata (a after Skuja, b ex Kisselev after Wołoszynska)
20. D. baltica (ex Kisselev after Wołozynska)

APPENDIX

Results of the intercalibration of brackish-water phytoplankton from Tvärminne Storfjärd, outer archipelago zone of the southern coast of Finland on 2.5.1980, 23.4.1982, 21.7.1982, 31.8.1982. A to F refer to different participating laboratories and planktologists. Nomenclature is according to Edler et al. (1984) (Designations are explained on p. 9-10).

2.V 1980	A	B	C	D	E	F
N. dubia W. Smith			+ o			
N. frigida Grun.	2	3	1-2	2 o	+	2
N. longissima (Bréb.) Ralfs	2	1	2-1		1	2
N. palea (Kütz.) W. Smith	2					
N. sigma (Kütz.) W. Smith			1-+ o			
Nitzschia (lanceolata-type)			1			
Nitzschia, sect. Fragilariopsis			+ o			
Nitzschia		1	1			
Naviculoid diatom					+	
Pinnularia quadratarea v. stuxbergii Cleve			+ o			
Rhoicosphenia abbreviata (C.A.Ag.) Lange-Bart.	1		+-1	1		
Stauroneis spicula Hickie			+ o			
Stauroneis			1			
Surirella angustata Kütz.			+ o			
S. ovalis Bréb.			+ o			
S. ovata Kütz.			+ o			
S. ovalis/ovata			1 o			
Surirella			+			
Synedra pulchella Ralfs			1			
S. rumpens Kütz.			+ o			
S. tabulata (C.A. Ag.) Kütz.		+	1	1 o		
S. tabulata v. acuminata (Kütz.) Grun.			2 o			
S. tabulata v. fasciculata			+ o			
S. ulna (Nitzsch.) Ehrenb.						
S. ulna v. danica (Kütz.) Grun.			+ o			
Synedra					+	
Tabellaria fenestrata (Lyngb.) Kütz.			+ o			
T. flocculosa (Roth) Kütz.	1 +					
Eutreptia				+		
Eutreptiella					+	
Euglena acus Ehrenb.				+ cf		
Pedinomonas mikron		+				
Pyraminomas			+	+		
Chlamydomonas		+			+	
Monoraphidium contortum (Thuret) Kom.-Lengn.	1			+		
M. setiforme (Nyg.) Kom.-Legn.		+				
Oocystis lacustris Chodat						1
Scenedesmus	1					1
Tetraedron minimum (A. Braun) Hansg.			+			
Diaphanoeca pedicellata			1			

2.V 1980	A	B	C	D	E	F
A. taeniata Grun.	4	4	4-5	5	4	5
Achnanthes			+ o			
Amphiprora paludosa W. Smith		+	+ o	+		
Amphora coffaeiformis (C.A. Ag.) Kütz.			+ o			
A. ovalis Kütz.		+	+ o			
A. ovalis v. pediculus Kütz.				+ o		
Bacillaria paxillifer (O.F. Müll.) Hendey			+ o			
Berkeleya rutilans (Trent.) Grun.			+ o			
Brebissonia boeckii (Ehrenb.) Grun.			+ o			
Cocconeis pediculus Ehrenb.			+ o	+ o		
C. scutellum Ehrenb.			+ o			
C. scutellum v. parva Grun.		+				
Cylindrotheca			1			
Cymbella ventricosa Kütz.	1			+ o		
Diatoma elongatum (Lyngb.) C.A. Ag.	4	5	5	4	5	4
D. elongatum v. tenue van Heurck				3 o		
D. vulgare Bory	1					
Diploneis sp.			+ o			
Epithemia sorex Kütz.			+ o			
Fragilaria brevistriata Grun.				+ o		
F. construens v. venter (Ehrenb.) Grun.			+ o			
Gomphonema olivaceum (Lyngbye) Kütz.			+ o ?			
Gomphonema			+ o			
Gyrosigma					+	
Licmophora gracilis (Ehrenb.) Grun.			1 cf			
Navicula gregaria Donkin			1 o			
N. hansenii			+ o			
N. lanceolata (= avenacea) (C.A.Ag.) Ehrenb.			1 o			
N. rostellata			+ o			
N. roteana			+ o			
N. tripunctata (= gracilis) (O.F.Müll.) Bory			1 o			
Navicula rhynchocephala Kütz.	1 +		1-+ o	+ o		
N. salinarum Grun.	1					
N. vanhoeffenii Gran		+	1 o	1	+	
Navicula			1			
Nitzschia acicularis W. Smith				1	+	
N. amphibia Grun.				+ o ?		
N. closterium (Ehrenb.) W. Smith				1 o ?		
N. cylindrus (Grun.) Hasle	1	3	1-4	2 o	1	3

Tvärminne Storfjärd st. XII 2.V 1980	A	B	C	D	E	F
Aphanizomenon flos-aquae (L.) Ralfs			1	+		
Oscillatoria sp.			1			
Dinophysis acuminata Clap & Lachm.		+		+	+	
Glenodinium paululum Lindem.				+ cf		
Glenodinium	1	+	1			
Gonyaulax catenata (Lev.) Kofoid	4	4	4-5	4	4	4
Gymnodinium	1	+	1			2
Paulsenella chaetoceratis (Apodinium)			+			
Peridinium hangoei Schiller	1	+	2			
Protoperidinium bipes (Pauls.) Balech	2	1	2-1	2	1	1
P. brevipes (Pauls.) Balech			1	2 cf		
P. granii (Ostenf.) Balech	2	3	2	2	1	1
Protoperidinium	1					
Ebria tripartita (Schum.) Lemm.	2	1	2	2	2	+
Ochromonas			1			
Dinobryon petiolatum Willén			1			
Actinocyclus octonarius Ehrenb.			+ o	+ o		
Chaetoceros ceratosporus Ost.			+			
C. holsaticus Schütt	4	4	5	4	4	+
C. septentrionalis Östrup	1	1	2-1	1	+	2
C. wighamii Brightw.	3	2	3		3	2
Chaetoceros		3		1		4
Cyclotella meneghiniana Kütz.			+ o	+ o		
Melosira arctica (Ehrenb.) Dickie	2	2	2	2	+	2
M. italica (Ehrenb.) Kütz.			+ o			
M. lineata (Dillw.) C.A. Ag.		+				
M. varians C.A. Ag.				+		
Rhizosolenia longiseta Zach.				+		
Skeletonema costatum (Grev.) Cleve	3	2	4-3	1	3	1
Thalassiosira baltica (Grun.) Ostenf.	1	1	1	2	1	1
Thalassiosira bramaputrae (Ehrenb.) Håk.	1	1	2-1	+ o	1	
T. guillardii Hasle		+	2 cf			
T. levanderi van Goor		2	2		+	
Thalassiosira 8-10 _m _					+	
Thalassiosira			2-+ o			
Achnanthes hauckiana Grun.			+ o	+ o		
A. lanceolata (Bréb.) Grun.				+ o		
A. lanceolata v. rostrata (Oestr.) Hust.				+ o		
A. lapponica Hust.			+ o cf			
A. lemmermannii Hust.	1 cf					

Tvärminne Storfjärd st. XII 23.IV 1982	A	B	C	D	E	F	G
Achroonema proteiforme Skuja			+ ?				
Aphanizomenon flos-aquae (L.) Ralfs			+				
Nodularia harveyana (Thwaites) Thuret				2			
Oscillatoria amphibia C.A. Ag			+ cf				
O. limnetica Lemm.					+		
Cryptomonas	+ spp	+ sp	1		1 spp	1	2
Katablepharis						+	
Rhodomonas							1
Dinophysis acuminata Clap. & Lachm.				+			
D. rotundata Clap. & Lachm.					+		
Gymnodinium simplex (Lohm.) Kof. & Swezy							+
Gymnodinium					?	x	3
Glenodinium gymnodinium Pernard					+		
G. penardiforme (Lind.) Schiller			+ cf				
Glenodinium	1	4			4		
Glenodinium/Gonyaulax catenata						1-2	
Gonyaulax catenata (Lev.) Kofoid	3(2)	3-4	3	3	2	2	3
G. grindleyi Reinecke							2
Oblea rotunda (Lebour) Balech	1						
Peridinium hangoei Schiller	1		+ cf	1		1 cf	
Protoperidinium bipes (Pauls.) Balech	+(1)	1-2	2	1	2	x	+
P. granii (Ost.) Balech	2(1)	1	+	1	1	1	+
Protoperidinium				1			
Ebria tripartita (Schum.) Lemm.	1(+)	+	2	2	+	1	
Chrysochromulin				1			
Prymnesium sp.						1	
Ochromonas					+		
Actinocyclus octonarius Ehrenb.			+ o				
Chaetoceros ceratosporus Ost.	2(3)	3	+	1	3	1	+
C. danicus Cleve		1					
C. holsaticus Schütt	2(3)	3	+	1	3	1	+
C. septentrionalis Östrup		2	1	1	2	2	
Chaetoceros similis Cleve			+ cf				
C. subtilis Cleve		2					
C. wighamii Brightw.	2(3)	4	2	3	4(3)	4	3
Chaetoceros	+						
Coscinodiscus granii Gough			+ cf o				
Cyclotella caspia Grun.						+ o	
C. meneghiniana Kütz.		+	1 o	+ cf			
Cyclotella	+						

23.IV 1982	A	B	C	D	E	F	G
Melosira ambigua (Grun.) O. Müller					+	+ o	
M. arctica (Ehrenb.) Dickie	2(3)	4	4	3	3	3	3
M. lineata (Dillw.) C.A. Ag.					+		
M. moniliformis (O.F. Müller) C.A. Ag.		+					
M. nummuloides (O.F. Müller) C.A. Ag.			+				
M. varians. C.A. Ag.			+				
Skeletonema costatum (Grev.) Cleve	2(4)	4	3	3	3	3	4
Stephanodiscus hantzschii Grun.						+ o	
Thalassiosira baltica (Grun.) Ost.	2	2	1	1	1	2	2
T. bramaputrae (Ehrenb.) Håk.						1 o	
T. guillardii Hasle	2					2 o	2( )
T. levanderi van Goor	1 (+)	2	+		1	2 o	2( )
Thalassiosira sp.						1	
Achnanthes brevipes C.A. Ag.						+ o	
A. delicatula (= hauckiana) (Kütz.) Grun.				+ o		1	
A. lanceolata (Bréb.) Grun.			+ o				
A. minutissima Kütz.						+ o	
A. taeniata Grun.	5	5	5	5	5	5	5
Amphiprora paludosa W.Smith v. paludosa			+ o				+
A. paludosa v. subsalina Cleve*			+ o				
Amphora coffaeiformis v. perpusilla (Grun.) Cleve		+					
A. lineolata Ehrenb.	+						
A. ovalis v. pediculus Kütz.						+ o	
Bacillaria paxillifer (O.F. Müll.) Hendey			+ o			+ o	
Brebissonia boeckii (Ehrenb.) Grun.						+ o	
Caloneis					+		
Ceratoneis arcus (Ehrenb.) Kütz.			+ o				
Cocconeis diminuta Pant.						+ o	
C. pediculus Ehrenb.			+ o			+ o	
C. placentula Ehrenb.			+ o			+ o	
C. scutellum Ehrenb.						+ o	
Cocconeis	+						
Cymbella cistula (Hempr.) Grun.			+ cf				
C. ventricosa Kütz.		+					
Diatoma elongatum (Lyngb.) C.A. Ag.	1(2)	1-2	2	2	1	2	2
D. elongatum v. tenuis van Heurck			1 o				
D. vulgare Bory	+						

23. IV 1982	A	B	C	D	E	F	G
D. vulgare v. constricta Grun.						+ o	
Diploneis papula (A.Sm.) Cl.			+ o				
D. smithii (Bréb.) Cleve						+ o	
Epithemia turgida (Ehrenb.) Kütz						+ o	
Fragilaria construens v. venter (Ehrenb.) Grun.						+ o	
F. pinnata Ehrenb.			+ o			+ o	cf
F. pinnata v. mutabilis						+ o	
Gomphonema parvulum (Kütz.) Grun.						+ o	
Gyrosigma distortum (W. Smith) Cleve			+ o				
G. fasciola (Ehrenb.) Griff. & Henfrey			+ o				
Gyrosigma						+ o	
Licmophora gracilis (Ehrenb.) Grun.	+				+		
Licmophora		1	+				
Mastogloia exigua Lewis						+ o	
Navicula cryptocephala Kütz.	1	+ o					
N. cryptocephala v. veneta (Kütz.) Cleve						+ o	
N. gregaria Donkin						+ o	
N. hansenii						+ o	
N. hungarica Grun.						+ o	
N. lanceolata (C.A.Ag.) Ehrenb.						1 o	
N. rhombica Greg.						+ o	
N. rhynchocephala Kütz.		1	+ o			+ o	
N. salinarum Grun.						+ o	
N. tenuipunctata						+ o	
N. tripunctata (O.F. Müll.) Bory						+ o	
N. vanhoeffenii Gran	1(2)	1	2	2	1	1 o	2
N. viridula Kütz.				+ o			
Navicula					+	+ o	+
Nitzschia acicularis W. Smith			1 +				
N. actinastroides (Lemm.) van Goor	+ cf						
N. closterium (Ehrenb.) W. Smith		1	+ cf o	1			
N. cylindrus (Grun.) Hasle	+		2	+ o	+	1	
N. frigida Grun.	1(2)	3	3	2	2	1	3
N. frustulum (Kütz.) Grun.						+ o	
N. hungarica Grun.			+ o				
N. intermedia Hantzsch						+ o	
N. longissima (Bréb.) Ralfs	1(2)	2		1	2	1	2
N. lorenzianus v. subtilis						+ o	
N. sigma (Kütz.) W. Smith			+ o			+ o	

23. IV 1982	A	B	C	D	E	F	G
N. tryblionella v. levidensis (W.Sm.) Grun						+ o	
Nitzschia					+	+ o	+
Opephora martyi Hérib.			+ o			+ o	
Opephora sp.						+ o	
Pinnularia quadratarea v. stuxbergii Cleve						+ o	
Pinnularia					+		
Pleurosigma					+		
Rhoicosphenia abbreviata (C.A.Ag.) Lange-Bart.					+	+ o	
R. curvata (Kütz.) Grun.			+	+			
Rhoicosphenia							+
Rhopalodia gibba v. gibba (Ehrenb.) O. Müller						+ o	
Stauroneis data						+ o	cf
Surirella ovalis Bréb.		+	+ cf				
S. ovata Kütz.	+ cf				+		
S. ovalis/ovata						+ o	
Synedra pulchella Ralfs			+ o			+	
S. rumpens Kütz.						+ o	
S. tabulata (C.A.Ag.) Kütz.	1		2 o	+	1	2	1
S. tabulata v. fasciculata (Kütz.) Grun.						1 o	
S. ulna (Nitzsch) Ehrenb.					1	1 ?	
S. vaucheriae Kütz.						+ o	
Synedra	1(+)spp		2-3				
Tropidoneis dannfeltii Cleve-Euler			+				
Bacillariales	+						
Euglena viridis (O.F. Müller) Ehrenb.		1	1 cf		1		
Euglena						x	
Eutreptia			1				
Eutreptiella	1(+)				1		1
Trachelomonas hispida (Perty) Stein em. Delf.			+ ?				
Euglenophyceae		+					
Mantoniella squamata (Manton et Parke) Desik.						3 ?	
Pedinomonas				1	1		1
Pyramimonas	1(2)		1	1	1	1	3
Chlamydomonas	2		+ o)	2	2	2	3
Carteria			+				

23. IV 1982	A	B	C	D	E	F	G
Pandorina morum (O.F.Müll.) Bory					+		+
Crucigenia	+						
Monoraphidium contortum (Thuret) Kom.-Legn.	1(+)		+				+
M. setiforme (Nyg.) Kom.-Legn.					+ cf		
Oocystis borgei Snow			+				
Oocystis lacustris Chodat							+
Pediastrum duplex Meyen			+				
Scenedesmus quadricauda Chodat	+						
Tetraëdron minimum (A. Braun) Hansg.			+				
Chlorohormidium flaccidum (A.Braun) Fott			+				
Koliella elongata Nygaard				1			
Staurastrum planktonicum Teiling			+				
Zygnema					+		
small monads	2						
monads varia	+						
Choanoflagellata						1	

Tvärminne Storfjärd st. XII 21.VII 1982	A	B	C	D	E	F	G	
Coelosphaerium kuetzingianum Nägeli						1		
Gomphosphaeria lacustris Chodat	+	2	2	1	2	3	3	
G. lacustris v. compacta Lemm.	+					2		
G. litoralis Häyrén	1							
Merismopedia warmingiana Lagerh.					+			
Microcystis reinboldii (Richt.) Forti		+	+	1	+(1)			
Achroonema	2 spp	2	+			1 ?	+	
Anabaena cylindrica Lemm.						2		
A. inaequalis (Kütz.) Born. & Flah.		+	+					
A. lemmermannii P. Richt.	1				+	2 cf		
A. spiroides Kleb.		+	+					
Anabaena	+				+(1)		+	
Aphanizomenon gracile (Lemm.) Lemm.			1					
A. flos-aquae (L.) Ralfs	3-4	5	5	4	5	5	5	
Lyngbya aestuarii (Mert.) Liebm.	1 cf					+		
L. limnetica Lemm.					+	+		
Nodularia spumigena Mert.	+-1	1	+		+(1)	3	1	
Oscillatoria agardhii Gom.	1							
O. limnetica Lemm.	+-1							
Chroomonas				1				
Cryptomonas	1	2	2		1(3)	2 spp		4
Rhodomonas minuta Skuja	2 ?							
Rhodomonas		3						
Dinophysis acuminata Clap. & Lachm.	4	4	4		4	4	5	
D. baltica (Pauls.) Kof. & Skogsb.				4		+		
D. norvegica Clap. & Lachm.	2-1				+	1	1	
D. rotundata Clap. & Lachm.		1	1			+		
Amphidinium sp.	1							
Amphidinium (cysts)	2							
Gymnodinium simplex (Lohm.) Kof. & Swezy		1	1			+		
Gymnodinium splendens Lebour	2 ?							
Gymnodinium	+-2						1	
Katodinium rotundatum (Lohm.) Fott	1							
Katodinium			+				+	
Glenodinium paululum Lindem.						+ cf		
Glenodinium					+(1)			
Gonyaulax catenata (Lev.) Kofoid						+		
G. grindleyi Reinecke	3-2		1				4	
Heterocapsa triquetra (Ehrenb.) Stein						+		
Oblea rotunda (Leb.) Balech	+-1				+			
Peridinium cinctum (O.F. Müller) Ehrenb.						2 cf		

21. VII 1982	A	B	C	D	E	F	G
P. hangoei Schiller					+	1 cf	
Peridinium			+		+(1)		
Protoperidinium brevipes (Pauls.) Balech.	1					3	
Ebria tripartita (Schum.) Lemm.	3-2	2	1	+	2(+)	3	2
Chrysochromulina	3-4	3	3	2	1(2)		
Prymnesium			+				
Bicocoeca ovata Lemm.					2 cf		
Dinobryon petiolatum Willén		1					
Ochromonas		+	+				
Paraphysomonas				1			
Uroglena americana Calkins		4	1				
Calycomonas wulffii Conr. & Kuff.	1						
Calycomonas		+					
Pedinella		3			+		
Pseudopedinella	1						
Actinocyclus octonarius Ehrenb.	2-1	+	3	+	1(2)	1 o	2
Chaetoceros cf. affinis Lauder	+						
C. borealis Bailey						+	
C. calcitrans (Paulsen) Takano	+ cf						
C. danicus Cleve	3-1	+	1		+	2	1
C. gracilis Schütt	2 ?		+				
C. subsecundum (Grun.) Hust.						+ cf	
C. wighamii Brightw.	+-1	1	1	2	+(1)	3	2-3
Chaetoceros holsaticus/wighamii nesting spores	+ o						
Coscinodiscus granii Gough	1		+		+		+
C. rothii (Ehrenb.) Grun						+ o cf	
Cyclotella caspia Grun.	+ o						
C. comta (Ehrenb.) Kütz.	+ o					+ o	
C. kützingiana Thwaites	+ o				+ cf		
C. meneghiniana Kütz.	+ o					+ o	
Leptocylindrus minimus Gran			+				
Melosira arctica (Ehrenb.) Dickie		1					
M. lineata (Dillw.) C.A. Ag.	+		+			3	+
M. moniliformis (O.F. Müller) C.A. Ag.						2	
Skeletonema costatum (Grev.) Cleve		1	1		+	2	+
Stephanodiscus astraea (Ehrenb.) Grun.	+ o cf						
Thalassiosira baltica (Grun.) Ost.	+ o	1	1		+		2
T. bramaputrae (Ehrenb.) Håk.	+ o						
T. levanderi van Goor	+ o						
Thalassiosira	+ o				+		

21.VII 1982	A	B	C	D	E	F	G
Achnanthes brevipes C.A. Ag.	+ o						
A. brevipes v. intermedia (Kütz.) Cleve						+ o	
A. delicatula (Kütz.) Cleve	+ o						
A. exigua Grun.	+ o						
A. taeniata Grun.	1 o					+	1 o
Achnanthes	+						
Amphiprora alata Kütz.	+ ?						+
A. paludosa W. Smith	+-1				+	+	
Amphora coffaeiformis (C.A. Ag.) Kütz.	+ o						
A. ovalis Kütz.	+ o	+	+			+ o	
A. ovalis v. pediculus Kütz.	+ o						
Asterionella formosa Hassall	1						
Bacillaria paxillifer (O.F. Müll.) Hendey	1	+			+	+ o	
Berkeleya rutilans (Trentep.) Grun.	+						
Brebissonia boeckii (Ehrenb.) Grun.	+ o						
Caloneis amphisbaena (Bory) Cleve							
v. amphisbaena						+ o	
v. subsalina (Donkin) Cleve	+ o					+ o	
Caloneis	+ o						
Cocconeis diminuta Pant.	+ o						
C. pediculus Ehrenb.	+ o					+ o	
C. placentula Ehrenb.	+ o					+ o	
C. scutellum Ehrenb.	+ o			+ o			
Cocconeis					+		+
Cymbella					+		
Diatoma elongatum (Lyngb.) C.A. Ag.	+-1	+	1		+	+ o	+
D. elongatum v. tenuis van Heurck						+ o	
D. vulgare Bory				+ o			
D. vulgare v. constricta Grun.	+ o						
Diploneis didyma (Ehrenb.) Cleve	+ o					+ o	
D. interrupta (Kütz.) Cleve						+ o	
D. smithii (Bréb.) Cleve	+ o					+ o	
D. stroemii Hust.	+ o						
Diploneis	+ o						
Epithemia sorex Kütz.	+ o					+ o	
E. turgida (Ehrenb.) Kütz.	+ o						+
E. zebra (Ehrenb.) Kütz.	+ o					+ o	
Fragilaria brevistriata Grun.	+ o						
F. construens (Ehrenb.) Hust.	+ o						
F. construens v. subsalina Hust.	+ o						

21.VII 1982	A	B	C	D	E	F	G
F. crotonensis Kitton							+
F. pinnata Ehrenb.	+ o						
Fragilaria	+						
Gomphoneis olivaceum (Lyngb.) Daws.	+ o						
Gomphonema exigua	+ o						
Gyrosigma distortum (W. Sm.) Cleve						+ o	
G. fasciola (Ehrenb.) Griff. & Henfr.	+ o						
G. strigilis (W. Sm.) Cleve	+ o						
Gyrosigma	+				+		
Gyrosigma/Pleurosigma							+
Licmophora gracilis (Ehrenb.) Grun.	+-1		+		+		
L. gracilis v. anglica (Kütz.) Perg.	+ o						
Licmophora	+ o					+ o	
Mastogloia elliptica (C.A. Ag.) Cleve	+ o						
M. pumila (Grun.) Cleve	+ o						
Navicula cryptocephala Kütz.						+ o	
N. cryptocephala v. veneta (Kütz.) Cleve	+ o						
N. gregaria Donkin	2 o						1
N. hansenii	+ o						
N. humerosa Bréb.	1 o		+			+ o	1
N. hungarica v. hungarica Grun.	+ o						
v. capitata (Ehrenb.) Cleve	+ o						
N. lanceolata (C.A. Ag.) Ehrenb.	+ o						
N. marina Ralfs	+ o						
N. plicata	+ o						
N. radiosa Kütz.	+ o						
N. rhynchocephala Kütz.	+ o					+ o	
N. rostellata Kütz.	+ o						
Navicula	+						
Nitzschia apiculata (Greg.) Grun.	+ o						
N. closterium (Ehrenb.) W. Sm.						+ o	
N. cylindrus (Grun.) Hasle						1 o	x
N. frustulum (Kütz.) Grun.	+ o						
N. hungarica Grun.						+ o	
N. longissima (bréb.) Ralfs	1		+		+		
N. paleacea Grun.	+ o						
N. punctata (W. Sm.) Grun.	1 o						
N. sigma (Kütz.) W. Smith	1 o					+ o	
N. sigmoidea (Nitzsch) W. Smith	+ cf		+		+ cf		
N. tryblionella Hantzsch						+ o	
N. tryblionella v. levidensis (W. Sm.) Grun.	+ o						

21.VII 1982	A	B	C	D	E	F	G
Nitzschia sect. Fragilariopsis	1 o						
Nitzschia	+ spp	+					
Opephora martyi Hérib.	1 o					+ o	
Pleurosigma elongatum W. Smith	1 o						
P. salinarum Grun.						+ o	
Rhoicosphenia abbreviata (C.A. Ag.) Lange-Bart.	1 o				+	+ o	
Rhopalodia gibba v. ventricosa (Kütz.) Grun.	+ o						
Rhopalodia						+ o	
Stauroneis spicula Hickie	+ o						
S. ovalis Bréb.						+ o	1
S. ovata Kütz.						+ o	
S. ovalis/ovata	1 o						
S. striatula Turpin	+ o				+ cf		
Surirella	+		+				
Synedra acus Kütz.	+ o			+ o		+ o	
S. pulchella Ralfs	+			+ o	+ cf	+ o	
S. tabulata (C.A. Ag.) Kütz.	2-1	+	+	1 o	+	2 o-	1
Synedra tabulata v. acuminata Grun.	2 o						
S. tabulata v. fasciculata (Kütz.) Grun.	1 o						
S. ulna v. danica (Kütz.) Grun.	+ o						
Synedra	+				+ spp		
Tabellaria fenestrata (Lyngb.) Kütz.	+ o					+ o	+
Tropidoneis dannfeltii Cleve-Euler	+ o						
Bacillariales					+		
Colacium vesiculosum Ehrenb.	+						
Eutreptia						+	
Eutreptiella	1	+			+		
Pedinomonas		2	+				
Pseudoscourfieldia		1					
Pyramimonas	2		+ spp	3	2	2	3
Chlamydomonas	1			+			
Carteria						1	
Gloeocystis planctonica (W. & G.S. West) Lemm.			+				
Botryococcus braunii Kütz.			+				
Crucigenia quadrata Morren						+	
Monoraphidium contortum (Thuret) Kom.-Legn.	2-1	2	+		3(1)		1
M. minutum (Nägeli) Kom.-Legn.					+	+	

21.VII 1982	A	B	C	D	E	F	G
M. mirabile (W. & G.S. West) Pankow					+		
Monoraphidium					+		
Oocystis borgei Snow	2-3	3	3		3(4)		3
O. lacustris Chodat	1	2	1		+	3	
O. submarina Lagerh.	+ ?			3		+	cf 1
Pediastrum boryanum (Turpin) Menegh.						+	
Scenedesmus acutus Meyen		+					
S.armatus (Chod.) G.M. Sm.	1 ?						
S. quadricauda Chodat			+			+	
Scenedesmus	+						
Tetraëdron minimum (A. Braun) Hansg.	1				+	+	
Planktonema lauterbornii Schmidle	1				+	+	1
Oedogonium		+					
Cosmarium			+				
Staurastrum planktonicum Teiling	+						
Staurastrum						+	
Spirogyra						1	+
monads varia					1(3)		

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	A	B	C	D	E	F	G	
Aphanothece stagnina (Spreng.) A.Br.					+ ?			
Coelosphaerium kuetzingianum Nägeli					1			
Gomphosphaeria lacustris Chod.	2	2		3	3	3	4	
G. lacutris v. compacta Lemm.		2			2			
G. litoralis Häyrén	3							
Merismopedia elegans					+			
Gloeocapsa minuta (Kütz.) Hollerb.					+ cf			
G. turgida (Kütz.) Hollerb.					+			
Gloeocapsa	+							
Merismopedia glauca (Ehrenb.) Nägeli					+	+		
Microcystis reinboldii (Richt.) Forti			2			+		
Achroonema	+	2			1 ?			
Anabaena inaequalis (Kütz.) Born. & Flah.	+	2-1		+				
A. lemmermannii P. Richter		1			3		+	
A. torulosa (Carm.) Lagerh.	1 ?							
A. cylindrica Lemm.					2			
Anabaena						+	1	
Anabaenopsis							(+)	
Aphanizomenon flos-aquae (L.) Ralfs	2	3	3	3	5	2	3	
Beggiatoa alba (Vauch.) Trev.							+	
Beggiatoa			+					
Lyngbya aestuarii (Mest.) Liebm.					+			
L. kuetzingii (Kütz.) Schmidle					+ cf			
L. limnetica Lemm.			1				+	
Nodularia spumigena Mertens	1	3	1	1	3	2	2	
Pseudanabaena catenata					+			
Oscillatoria tenuis C.A. Ag.					+			
Phormidium autumnale (C.A. Ag.) Gom.	+							
Spirulina major Kütz.					1	+		
S. subsalsa Örst.		1			+		+	
S. tenuissima f. subsalina					+			
Cryptomonas	+ spp	1 spp			2 spp			1
Rhodomonas minuta Skuja		1						
Prorocentrum balticum (Lehm.) Loebl. III	1							
Dinophysis acuminata Clap. & Lachm.	4	3-5		2	3	4	3	
D. baltica (Pauls.) Kof. & Skogsb.			1					
D. norvegica Clap. & Lachm.	3	1-4	+	3	2	4	3	
D. rotundata Clap. & Lachm.	+				+	+		
Amphidinium cysts		1						

31.VIII 1982	A	B	C	D	E	F	G
Gymnodinium	1	1-2					
Glenodinium		2 ?					
Gonyaulax grindleyi Reinecke	2	1-2		2		2	
Heterocapsa triquetra (Ehrenb.) Stein	2				2	+	+
Oblea rotunda (Leb.) Balech	1			1			1
Peridinium cinctum (O.F. Müller) Ehrenb.					2 cf		
P. hangoei Schiller					+ cf		+
Peridinium	+			+			+spp
Protoperidinium bipes (Pauls.) Balech	2		+	+			
P. brevipes (Pauls.) Balech	1	1-2			1	+	2
P. granii (Ost.) Balech					1		
Scrippsiella trochoidea (Stein) Loebl. III	1 ?						
Ebria tripartita (Schum.) Lemm.	5	4-5	2	4	4	5	5
Chrysochromulina	2						
Prymnesium	+						
Bicocoeca ovata Lemm.					3		
Dinobryon petiolatum Willén	+						
Ochromonas	1	2 ?		1			
Uroglena americana Calkins	1						
Calycomonas ovalis Wulff							+
C. vangoori (Conr.) Lund	+						
C. wulffii (Conr.) Kuffer.		1					
Chrysococcus	+						
Pedinella							+
Actinocyclus octonarius Ehrenb.	2	2	1	+	+ o	1	2
Chaetoceros cf. affinis Lauder		1			+		
C. ceratosporus Ost.	2	1		+		x ?	1
C. danicus Cleve	2	2-4	3	1	1	3	2
C. holsaticus Schütt					3		
C. subtilis Cleve					+ cf		
Chaetoceros wighamii Brightw.	4	3-4	4	1	3	4	2
Coscinodiscus granii Gough	+	1			+ o	+	+
Cyclotella striatula						+ ?	
Melosira granulata (Ehrenb.) Ralfs					1		
M. lineata (Dillw.) C.A. Ag.	2	2-3	1	3		2	1
M. moniliformis (O.F. Müller) C.A. Ag.					1		+
M. nummuloides (Dillw.) C.A. Ag.					1		
M. varians C.A. Ag.	+			1			
Rhizosolenia minima Lev.	+	1					2
Skeletonema costatum (Grev.) Cleve	1	2	+	1	1	2	2
Thalassiosira baltica (Grun.) Ost.	+	2				2	+

31.VIII 1982	A	B	C	D	E	F	G
T. bramaputrae (Ehrenb.) Håk.					+ cf o		
T. nordenskiöldii Cleve					+ cf		
Achnanthes brevipes C.A. Ag.	1 o						
A. delicatula (Kütz.) Grun.	1						
A. gibberula (Grun.)	+ o						
A. exiqua Grun.	+ o						
A. hauckiana Grun.					+		
A. taeniata Grun.	1	1 o			2		+
Amphiprora alata Kütz.		2				3	
A. paludosa W. Smith	+	1-3		+	1 o		1
A. paludosa v. subsalina Cleve					1 o		
Amphora coffaeiformis (C.A. Ag.) Kütz.		1					
A. lineolata		1					
A. ovalis Kütz.	1	1		+		+	
A. ovalis v. pediculus Kütz.		+ o			1 o		
Amphora	+	2				+	
Asterionella formosa Hassal							(+)
Bacillaria paxillifer (O.F. Müller) Hendey	+	1			2 o	1	+
Brebissonia boecki (Ehrenb.) Grun.	+	+ o					
Caloneis amphisbaena (Bory) Cleve		+ o					
amphisbaena v. subsalina (Donkin) Cleve					+ o		
C. bacillum v. lancettula		+ o					
Cocconeis pediculus Ehrenb.		1-2			+ o		
C. placentula Ehrenb.		1			+ o		+cf
C. placentula v. euglypta (Ehrenb.) Cleve					+ o		
Cocconeis scutellum Ehrenb.	+	+ o	+ o		+ o	+	
C. scutellum v. parva Grun.	+						
Cocconeis						+	+
Cymbella ventricosa Kütz.						1	
Cymbella		+ o					+
Diatoma elongatum (Lyngb.) C.A. Ag.	1	+			+ o		
D. elongatum v. tenuis					+ o		
D. vulgare Bory			+ o				
D. vulgare v. constricta Grun.		1			1 o		
Diploneis smithii (Bréb.) Cleve		1 o			+ o		
D. stroemii Hust.		+ o					
Diploneis		+					
Epithemia sorex Kütz.	1	2		+	+ o	+	
E. turgida (Ehrenb.) Kütz.		1-2			+ o		

31.VIII 1982	A	B	C	D	E	F	G
E. zebra (Ehrenb.) Kütz.		+ o					
Epithemia			+				+
Fragilaria construens (Ehrenb.) Grun.	+ o						
Fragilaria construens v. venter (Ehrenb.) Grun.		+ o			+ o		
F. crotonensis Kitton	1	1		+		+	(+)
F. pinnata Ehrenb.					+ o		
Fragilaria		+-1					
Gomphoneis olivaceum (Lyngb.) Dawson		+ o					
Gomphonema olivaceum (Lyngb.) Kütz.		1 +					
Gyrosigma balticum (Ehrenb.) Cleve		+ o cf				+ o	
G. distortum (W. Smith) Cleve		1			+ o		
G. fasciola (Ehrenb.) Griff. & Henfr.	1						
G. scalproides v. eximia (Thwaites) Cleve					+ o		
Gyrosigma	+	2 3					+
Gyrosigma/Pleurosigma	3					2	
Licmophora communis (Heib.) Grun.		1			1 o		
L. gracilis (Ehrenb.) Grun.	1	+ o		2	+ o		1
Licmophora		1	+			2	
Mastogloia elliptica C.A. Ag.		+ o					
M. exiqua Lewis		+-1 o					
M. smithii Thwaites					+ o		
Navicula gregaria Donkin		2					
N. halophila (Grun.) Cleve					+ o	+	
N. humerosa Bréb.	+	+ o			+ o	+	
N. marina Ralfs		+ o					
N. paleacea Grun.		2 cf					
N. peregrina (Ehrenb.) Kütz.		+ o	1 o			+ ?	
N. plicata		+ o	1 o			+ ?	
N. pusilla (Kütz.) Grun.		+ o					
N. radiosa Kütz.		+ o					
N. rhombica Gregory		1					
N. rhynchocephala Kütz.		+ o	1 o			+	
N. viridula Kütz.					+ o		
Navicula	+			+		+	
Nitzschia acicularis W. Smith	1 cf	1	1	+	1 o		
N. actinastroides (Lemm.) van Goor		2 ?				1 cf	
N. apiculata (Greg.) Grun.		1 cf					
N. closterium (Ehrenb.) W. Smith	1	2 ?	1				1(2)
N. cylindrus (Grun.) Hasle					+ o	+	
N. dubia W. Smith		+ o					

31.VIII 1982	A	B	C	D	E	F	G
N. frustulum (Kütz.) Grun.		+ o					
N. frustulum v. subsalina Hust.					+ o		
N. gandersheimensis Krasske		1					
N. hungarica Grun.					+ o		
N. hybrida Grun.					1 o		
N. longissima (Bréb.) Ralfs	3	1-3	2	3			3(2)
N. longissima v. closterium						+	
N. longissima v. reversa					+ o		
N. punctata (W. Smith) Grun.		1 o			+ o		
N. sigma (Kütz.) W. Smith		1 ?	+		+ o		
N. tryblionella Hantzsch					+ o		
N. tryblionella v. ambigua					+ o ?		
N. tryblionella v. levidensis (W.Sm.) Grun.		+ o					
Nitzschia sect. Fragilariopsis		+ o					
Nitzschia sect. lanceolatae		+ o					
Nitzschia	+	1-2					+
Opephora martyi Hérib.		1-2 o			+ o		
Pinnularia quadratarea v. stuxbergii Cleve		+ o					
Pinnularia	+	+ o				+	
Pleurosigma angulatum (Quek.) W. Sm.		+ ?					
P. elongatum W. Smith		+ o			+ o		
Pleurosigma sp.		+ o					
Rhoicosphenia abbreviata (C.A. Ag.) Lange-Bart.	+	1 o			+ o		+
Rhopalodia gibba (Ehrenb.) O. Müll.		+ o					
R. gibba v. ventricosa (Kütz.) Grun.	+				+ o		
Stauroneis gregory Ralfs		+ o					
S. spicula Hickie		1-3			1 o		
Stenopterobia		2					
Surirella gemma (Ehrenb.) Kütz.		+			+ o		
S. ovalis Bréb.	+	2 ?			+ o	+	
S. ovalis v. baltica					+ o ?		
S. ovalis v. crumena (Bréb.) van Heurck				+			
S. ovalis v. salina					+ o ?		
S. ovata Kütz.		2 ?		1	+ o		
S. ovalis/ovata		1					
S. striatula Turpin		+	1		+ o		
Surirella						+	
Synedra acus Kütz.							+

31.VIII 1982	A	B	C	D	E	F	G
S. pulchella Ralfs					+ o		
S. tabulata (C.A. Ag.) Kütz.	1	2-3	+ o	+	2 o	3	1
S. tabulata v. acuminata Grun.		3 o					
S. ulna (Nitzsch) Ehrenb.	+		+	+			1
Synedra						3	+
Tropidoneis dannfeltii Cleve-Euler		+-1					
Pedinomonas			1 ?				
Pyramimonas		1			2-3		+
Monoraphidium contortum (Thuret) Kom.-Legn.							+
M. minutum (Nägeli) Kom.-Legn.	+				+		
Oocystis borgei Snow	3	2-3		3	+	3-4	4
O. lacustris Chodat		1-2		2	+		
O. submarina Lagerh.			1				
Pediastrum boryanum (Turp.) Menegh.					+		
P. kawraiskyi Schmidle					+		
Scenedesmus ecornis (Ralfs) Chod.					+		
S. quadricauda Chod.					+		
Scenedesmus		+					
Trochiscia		1					
Planktonema lauterbornii Schmidle						+	
Mougeotia	1			+		1	
Spirogyra		3			3	1	+
Ectocarpus confervoides					+		
Pylaiella littoralis					1		
monads varia.							+

FINNISH-SOVIET INTERCALIBRATION OF SAPROPHYTIC BACTERIA ANALYSES

Astrid Saava[1] and Ilkka Rinne[2]

INTRODUCTION

The term saprophytic bacteria (or saprophyte) is applied to all aerobic heterotrophic bacteria which are able to develop on agar media, and which can be counted by means of the plate method (Rheinheimer 1977). These are forms which have a high metabolitic activity and thus react more quickly to changes in their environment than the rest of the bacteria. Saprophytes thus serve as a good indicator of the pollution load of the water at a given time (Bonde 1975; Rheinheimer 1977).

The first intercalibration of the analyses used for enumerating saprophytes was carried out within the framework of the Finnish-Soviet intercalibration of biological parameters for monitoring the conditions of the Gulf of Finland (Järvekülg et al. 1980). The results revealed only small differences (though statistically significant in some cases) in saprophyte colony count obtained after 2 days. The colony counts obtained after 2 weeks incubation, and the increase in the number of colonies during a period of 12 days differed considerably. This was due to the use of different counting methods and media. The spread-plate method gave higher colony counts than the pour-plate method. Higher counts were also obtained when NaCl or sea-salt were added to the media and the dilution water (Barinova et al. 1980).

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The results of the intercalibration indicate that coordination and unification of marine microbiological methods should be continued. This need has further increased following the recommindations that bacteriological parameters should be included in the monitoring programs (Rheinheimer 1983; Saava and Lääne 1983; Seki 1982; Väätänen 1981). However, as was earlier mentioned the next intercalibration should not be arranged until the effect of NaCl supplement in media and dilution water has been studied and different types of media compared (Järvekülg et al. 1980).

1. EFFECT OF NaCl SUPPLEMENT IN MEDIA AND DILUTION WATER ON THE COLONY COUNTS OF SAPROPHYTES

1.1 Material and methods

The studies on the effect of NaCl supplement in agar media and dilution water on the colony counts and their increase in seawater samples during the 12-day period were carried out by the Research Laboratory of Sanitary Engineering of the Tallinn Polytechnical Institute (Saava A. and others) in 1979-1980.

The samples for the analyses were collected from the surface water layer at different stations in the Tallinn Bay area at different times of the year. A Simple 1-litre sampler was used. The surface salinity at the stations varied between 5 °/₀₀ and 7 °/₀₀.

The Soviet standard nutrient agar (prepared by Dagestan Research Institute, dissolved in distilled water, sterilized) and sterilized Tallinn tap-water (as diluent) were used. For order to determine the effect of NaCl supplement in the media and dilution water on the colony counts of seawater samples, the standard agar had earlier been dissolved in 5 °/₀₀ NaCl solution and sterilized. The dilution water was also supplemented with 5 °/₀₀ NaCl.

The pour plate techinique was used. The inoculated agar plates were kept in a thermostat at 20°C. The bacterial colonies were counted after 2 days and then again 2 weeks later. Three replicate plates were prepared from each dilution.

Simple statistical treatment was carried out on the data. The significance of differences between the mean values of colonies counted on the plates with the NaCl supplement in the media or dilution water, and without it, was evaluated using the t-test.

1.2 Results

The results for colony counts obtained with standard agar containing 5 °/₀₀ NaCl supplement, and without, are summarized in Table 1.

The ratios of colony counts on agar plates with NaCl supplement to those on agar plates without NaCl supplement were ca. 1 after two days and after two weeks. The ratio values for the two periods did not differ from each other either. Thus adding 5 °/₀₀ NaCl supplement to the Soviet nutrient agar had no effect on the colony counts of saprophytes in seawater samples, nor on the increase in their counts during the 12-day period, in comparison with the same agar without the supplement. Dilution with tap-water (without NaCl supplement) might stress the brackish water bacteria so that they are unable to grow on agar.

The data concerning the effect of NaCl supplement in the dilution water on the colony counts of saprophytes are presented in Table 2.

The use of dilution water containing 5 °/₀₀ NaCl supplement resulted in colony counts 39 % and 46 % higher than those without this supplement after 2 days and after 2 weeks, respectively. The differences were statistically significant at the 0,001 level.

Rheinheimer (1977) obtained, as a rule, higher colony counts of saprophytes in samples from the Kiel Bight (SW Baltic Sea) on plates of higher salinity.

TABLE 1. Colony counts of saprophytes on Soviet standard nutrient agar with and without NaCl supplement.

	Number of colonies on agar				Ratio of colony counts			
	without NaCl supplement		with NaCl supplement		between incubation periods		between with and without NaCl	
	after 2 days A	after 2 weeks B	after 2 days C	after 2 weeks D	without NaCl B/A	with NaCl D/C	after 2 days C/A	after 2 weeks D/A
n = 34								
range:								
min - max	13 - 352	25 - 427	7 - 355	22 - 428	1,08 - 3,92	1,04 - 3,45	0,54 - 1,65	0,43 - 2,14
$\bar{x}$					1,91	1,98	0,98	1,04
SD					0,72	0,73	0,22	0,32
$t = (\bar{x}-1)/(SD/\sqrt{n})$							-0,53	0,73
P							-	-

TABLE 2. Colony counts of saprophytes on Soviet standard nutrient agar using dilution water with and without NaCl supplement.

	Number of colonies on agar				Ratio of colony counts			
	dilution water without NaCl		dilution water with NaCl		between incubation periods		between with and without NaCl	
	after 2 days A	after 2 weeks B	after 2 days C	after 2 weeks D	without NaCl B/A	with NaCl D/C	after 2 days C/A	after 2 weeks D/B
n = 34								
range:								
min - max	16 - 300	25 - 427	10 - 430	14 - 518	1,08 - 3,66	1,06 - 4,38	0,56 - 2,35	0,50 - 2,61
$\bar{x}$					1,85	1,99	1,39	1,46
SD					0,62	0,78	0,46	0,47
$t = (\bar{x}-1)/SD/\sqrt{n})$							4,94	5,95
P							<0,001	<0,001

The above results stress the necessity of using 5 °/₀₀ NaCl (or marine salt) supplement in the dilution water when enumerating saprophytes in brackish water, or to use aged brackish water for dilution, as has been recommended for marine microbiological studies in the Baltic Sea (Maciejowska et al. 1981).

2. COMPARISON OF MEDIA

2.1 Material and methods

Two different media commonly used for enumerating saprophytes in Finland and the Soviet Union were compared. Standard plate-count agar prepared by Difco (Difco plate agar) was obtained from Helsinki City Water Conservation Laboratory. Soviet nutrient agar prepared by Dagestan Research Institute was obtained commercially.

The seawater samples used in comparing media were taken at the same stations and by the same techniquae as for the study on the effect of NaCl supplement in the media and dilution water (see above).

The samples were plated in both Difco agar media and Soviet nutrient agar media. The poured agar plates (three replicates) were incubated at 20°C in darkness. The bacterial colonies were counted both 2 days and 2 weeks later. The results were analysed statistically using the t-test.

2.2 Results and discussion

In comparative tests on the seawater samples Difco plate agar gave 140 % and 216 % higher colony counts of saprophytes than those on Soviet nutrient agar after incubation periods of two days and two weeks, respectively (Table 3.) The differences were statistically highly significant ($P < 0.001$).

Apparently, Difco plate agar, having a more varied composition, selected a wider range of different physiological types of bacteria than the Soviet nutrient agar did.

TABLE 3. Colony counts of saprophytes on the Soviet standard nutrient agar and Difco Plate count agar.

	Number of colonies on agar				Ratio of colony counts			
	on the Soviet nutrient agar		on the Difco agar		between incubation periods		between agars	
	after 2 days A	after 2 weeks B	after 2 days C	after 2 weeks D	Soviet agar B/A	Difco agar D/C	after 2 days C/A	after 2 weeks D/B
n = 25								
range: min - max	3 - 130	6 - 200	4 - 278	12 - 390	1,08 - 6,50	1,29 - 12,46	1,00 - 5,76	1,04 - 7,40
$\bar{x}$					2,45	3,48	2,40	3,16
SD					1,30	2,44	1,25	1,46
$t = (\bar{x}-1)/(SD/\sqrt{n})$							5,60	7,40
P							<0,001	<0,001

Other studies also indicate that media of different composition produce the different colony counts of saprophytes in water samples (Rheinheimer 1977; Väätänen 1981).

The choice of medium composition depends on the aim of study. No data are available about the most suitable medium for microbiological monitoring of the Baltic Sea. Difco plate agar (ZoBell's medium 2216E) has often been used for microbiological studies in the Baltic Sea (e.g. Väätänen 1976, Rheinheimer 1977). However, Väätänen (1977) indicated that this medium did not give maximal numbers of colony counts on the Baltic Sea water in the Tvärminne area.

Comparable data on bacterial colony counts can only be obtained when the same medium is used. Attention should be paid to improving the medium composition in order to achieve maximal recovery of bacterial colonies in the Baltic Sea water.

3. THE SECOND FINNISH-SOVIET INTERCALIBRATION OF SAPROPHYTES ANALYSES

3.1 Introduction

The second intercalibration study of analyses for the enumeration of saprophytes was arranged on October 27-30 1980 in Tallinn. The aim of this intercalibration exercise was to determine the comparability of the results obtained by different laboratories (researchers) working under almost identical conditions, but using their own procedures and equipment.

The researchers and laboratories participating in this intercalibration exercise were:
I. Rinne from the Helsinki City Water and Sewage Works, Water Conservation Laboratory (WL);
R. Raud and A. Saava from the Sanitary Engineering Laboratory of the Tallinn Polytechnical Institute (TPI).

3.2 Material and methods

Seawater samples were collected at the two stations in the Tallinn Bay area at the depths approximately 30 cm below the surface on October 27. A simple 1-litre sampler was used. The samples were returned to the TPI laboratory immediately after collection and refrigerated in the sampling bag. The subsampling was carried out in the morning of October 28 before starting the analyses. Each participant used their own subsampling bottles and own cleaning procedures.

The participants were requested to analyse each of the subsamples in at least three dilutions (10^{-2}, 10^{-3} and 10^{-4}), and eight replicates of each dilution, using both Difco plate count agar and Soviet standard agar in parallel, and sterilized Tallinn tap-water with 5 °/₀₀ NaCl supplement as the diluent. The media and dilution water were prepared in the same way. The pour-plate technique was used by both laboratories. The subsamples were carefully agitated. Sampler for dilution were withdrawn from the subsampling bottle with a sterile pipette and transferred aseptically to a sterile glass dilution test-tube. 1 cm^3 of each dilution was pipetted into a sterile Petri dish and about 10 cm^3 of molten agar added and mixed. A 1 ml pipette was used for each dilution. WL used sterile plastic Petri dishes with a diameter of 9,5 cm.

The inoculated agar plates were inverted and incubated in a thermostat at 20°C. Bacterial colonies were counted on the agar plates by I. Rinne and R. Raud on the morning of October 30, i. e. 2 days after inoculation.

Calculations were made on the total number of bacterial colonies. The following parameters were calculated:
- arithmetical mean of eight replicates ($\bar{x}$);
- standard deviation (SD);
- coefficient of variation (CV %).

The results were compared using analysis of variance (three-way).

3.3 Results and discussion

The results of the intercalibration study are summarized in Table 4 and evaluated statistically in Table 5.

The third dilution (10^{-3}) of both samples had a saprophyte density of suitable for enumerating them by the pour-plate method. The mean values of the colony counts on plates reported for sample A and B ranged from 43,5 to 66,4 and from 47,9 to 85,4, respectively. The coefficient of variation varied from 7,9 to 16,9 % and from 8,4 to 22,0 %. The deviation of the replicates did not differ significantly between the laboratories according to the F-test (Table 5).

Although the method, media and composition of the dilution water used by both laboratories were the same, the results obtained by the two laboratories differed slightly.

For example, TPI obtained higher colony counts than WL, apart from sample A on the Soviet standard agar. TPI also obtained higher colony counts on the Difco plate-count agar than on the Soviet standard agar. The results submitted by WL for Difco plate-count agar and Soviet standard agar were in fairly close agreement.

TABLE 4. Colony counts of saprophytes after 2 days in intercalibrated samples.

Laboratory	Parameter	Sample A Difco agar	Sample A Soviet agar	Sample B Difco agar	Sample B Soviet agar
		dilution, cm^3			
		10^{-3}	10^{-3}	10^{-3}	10^{-3}
WL		52	41	51	45
		55	45	66	69
		45	44	70	39
		51	48	54	44
		44	37	60	42
		63	46	52	56
		46	42	40	51
		42	45	53	37
	$\bar{x}$	49,8	43,5	55,8	47,9
	SD	7,0	3,4	9,4	10,5
	CV %	14,0	7,9	16,9	22,0
TPI		72	56	92	80
		63	44	86	68
		57	36	85	66
		50	45	87	69
		73	48	81	75
		60	50	90	66
		71	60	92	52
		85	42	70	71
	$\bar{x}$	66,4	47,6	85,4	68,4
	SD	11,2	7,7	7,2	8,1
	CV %	16,9	16,2	8,4	11,8

According to the three-way analysis of variance (Table 5), the differences between the laboratories and between the two types of agar were statistically significant.

The following may be factors contributing to the differences between the results: researcher, dilution, pipette, individual plate error etc. Some significant differences associated with the procedure of inserting a pipette into a subsample or dilution tube, withdrawing an aliquot to inoculate into a plate, and counting the colonies, were found.

TABLE 5. Three-way analysis of variance of the results of the 2nd Finnish-Soviet intercalibration of saprophyte analyses.

Source of variation	d.f.	Variance		F	P
Between					
–samples	1	V1	2512	V1/V4 = 7,50	c. 0,05
–laboratories	1	V2	5023	V2/V4 = 15,0	< 0,05
–agars	1	V3	2488	V3/V4 = 7,41	c. 0,05
Error	4	V4	335,5	V4/V5 = 4,79	< 0,01
Inside groups	56	V5	70,02		
–from WL	28	V6	65,00		
–from TPI	28	V7	75,05	V7/V6 = 1,15	–

4. CONCLUSIONS

1. The NaCl supplement in the dilution water had a significant effect on the final colony counts of saprophytes in marine water. The effect in the case of the nutrient media was negligible. The use of NaCl supplement in the dilution water of aged brackish water as the diluent should be adopted for marine microbiological analyses.

2. Clear differences were found in the colony counts of saprophytes on Difco plate count agar and Soviet standard agar. The Difco plate count agar gave higher colony counts than Soviet standard agar. Comparable data can only be obtained when the same medium in used.

3. The results of the second intercalibration exercis saprophytes indicated that when the same media and dilution water were used, then the differences between the results obtained by the two laboratories were small, although statistically significant in some cases. The main reasons for the differences were associated with personell and procedures.

4. Intensive investigations should be made on the medium composition, sampling and storage procedures presently used by the microbiologists, in order to be able to recommend which are the best for studies on the Baltic Sea.

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A COMPARISON OF GELMAN AND SYNPOR MEMBRANE FILTERS FOR RECOVERING COLIFORM BACTERIA FROM SEA WATER

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INTRODUCTION

The use of the membrane filter technique in water quality analysis is well established and has been accepted as a standard method for evaluating bacterial water quality in many countries (Voda pitevaja 1973; Standard methods 1975; Unificirovannye metody 1977). However, it is now realized that different commercial brand membranes can vary in their capacity to capture, resuscitate, and grow microorganisms (Green et. al. 1975; Lin 1976; Søgaard 1976; Tobin and Dutka 1977). The reason for this has been attributed to differences in the morphological structure of the filters (Sladek et al. 1975; Standridge 1976). The standard methods impose no requirements on water laboratiories with regard to the choice and quality of the membrane filters used.

In the Soviet Union acetyl-cellulose membrane filters manufactured by the Mytiscinski Factory are mainly used. Membrane filters made by the Czeckoslovakian firm SYNPOR are also in use. The latter filters have been used for microbiological studies on the Baltic Sea at the Tallinn Polytechnical Institute (Saava 1985; Saava and Lääne 1984). The comparison of coliform bacteria recovery by SYNPOR and Mytiscinski filters revealed that colony counts obtained on

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SYNPOR filters were not statistically different (at the 5 % significant level) from counts made on Mytiscinski filters (Tamm and Saava 1980).

In Finland, membrane filters manufactured by the firms GELMAN, Sartorius and Millipore are generally used. The Helsinki City Water Conservation Laboratory uses GELMAN filters in the bacteriological monitoring of the sea around Helsinki.

The Finnish-Soviet intercalibration of sanitary-indicator bacterial analyses showed that colony counts of coli bacteria in the two countries were not directly comparable. The differences in the results were probably caused by the different media and membrane filters used. This being the case, it was considered necessary to compare the membrane filters used for enumarating coli bacteria in both countries (Raud et al. 1980). A series of experiments were carried out by the Sanitary Engineering Laboratory of the Tallinn Polytechnical Institute (TPI) and by the Water Conservation Laboratory of the Helsinki City Water and Sewage Works (WL) to compare the SYNPOR and GELMAN membrane filters.

MATERIAL AND METHODS

Membrane filters. The following two commercial brands of 0.45 µm porosity membrane filters were compared: GELMAN GN-6 and SYNPOR N:o 7. Both brand of filters were sterilized by boiling for 30 min in distilled water, the water being changed 3-5 times (TPI). At WL only the SYNOR filters were washed and boiled; the GELMAN filters were sterile and individually packed. The same lot of both makes of filter were used throughout the study (different lots in both laboratories). At WL the SYNPOR filters were trimmed to a diameter of 50 mm.

Water samples. Water from the Baltic Sea was used. The samples were collected in sterile bottles from the surface water layer in Tallinn Bay (TPI) or off Helsinki (WL), and immediately returned to the laboratory (TPI or WL). The samples were diluted when necessary to reduce the coli bacteria density to the countable range for the membrane filters, using sterilized tap-water (TPI) or buffered water (WL) at room temperature. TPI counted the oxidase-negative and lactose-positive coli bacteria on Endo agar; these bacteria were enumerated using standard Soviet methods (Voda pitevaja 1973; Sidorenko 1978). WL counted faecal coliform bacteria on MFC agar (Geldreich et al. 1965) according to the Finnish standard SFS 4088.

Procedures. Sea-water samples (or dilutions) were filtered in appropriate volumes using a Seitz (TPI) or Sartorius metallic (WL) filtering apparatus. Three (TPI) or ten (WL) replicates were prepared from each samples on GELMAN and on SYNPOR filters. The filters were plated on Endo agar and incubated at 37°C for 24 h (TPI), or on MFC agar and incubated at 44°C for 22 h (WL). The number of colonies was counted in a counting device at 2 x (TPI) or 4 x (WL) magnification. Only those filters with less than c. 100 colonies were examined. Only blue or blueish were counted on MFC agar.

The technical work was performed by K. Iga and A. Raiet (TPI) and by I. Aaltonen and M. Paasila (WL) in 1980-1981.

RESULTS AND DISCUSSION

Mean values were calculated from three replicates in the case of determinations made at TPI. The data are presented in Table 1. The results for WL are presented in Table 2.

Comparison of the recovery of oxidase-negative coli bacteria on GELMAN and SYNPOR filters showed that the GELMAN filters recovered 25 % more colonies. The difference was statistically significant at the 0.1 % level. When the recovery of lactose-positive coli bacteria by these filters was compared, the GELMAN filters had a 35 % higher recovery, also statistically significant at the 0.1 % level.

When the recovery of faecal coliform bacteria (WL, MFC agar, Table 2) was compared there was a statistically significant difference between GELMAN and SYNPOR in only one out ten samples examined.

The results indicate that these two commercial brands may differ in their capacity to recover coli bacteria. In a similar investigation, Presswood and Brown (1973) arrived at the same conclusion. They compared GELMAN and Millipore membrane filters and found GELMAN filters recovered statistically more colonies from pure cultures of *Escherichia coli* than Millipore filters. Schaeffer et al. (1974) examined natural samples and found no significant differences in the efficiency of the recovery of faecal coliform bacteria on GELMAN and Millipore filters. However, higher counts of total coliforms were obtained with GELMAN filters.

Dutka et al. (1974) compared membrane filters manufactured by GELMAM, Millipore and Sartorius. Their studies indicated that the various brands differed as regards recovery of total coliforms, faecal coliforms, faecal streptococci and heterotrophs. Sladek et al. (1975) demonstrated that the morphological structure of the filter material was a critical factor. The pore surface opening diameter seems to be a primary determinant of faecal coliform growth on membrane filters.

Tamm and Saava (1980) compared SYMPOR and Mytiscinski membrane filters and obtained statistically more colonies of enterococci on Mytiscinski filters. Colony counts of oxidase-negative and lactose- positive coli bacteria were not statistically different on the compared filters.

The finding that different makes of membrane filter vary in their capacity to recover coli bacteria suggests that there is a need for further investigation of their relative efficiencies, and to identify the reason for the difference as far as their effect on the propagation of bacteria in concerned. The selection of membrane filters should be done after careful deliberation.

TABLE 1. Mean counts of three replicates on membrane filters of coli bacteria (TPI).

Sample N:o	Oxidase-negative coli bacteria			Lactose-positive coli bacteria		
	GELMAN filter	SYNPOR filter	G/S	GELMAN filter	SYNPOR filter	G/S
1	78	92	0,85	68	78	0,87
2	82	95	0,86	74	78	0,95
3	28	24	1,17	24	20	1,20
4	50	26	1,92	44	25	1,76
5	104	118	0,88	98	106	0,92
6	58	32	1,81	46	22	2,09
7	24	22	1,09	18	13	1,38
8	20	12	1,67	17	8	2,13
9	34	34	1,00	29	27	1,07
10	79	64	1,23	67	56	1,20
11	44	40	1,10	36	25	1,44
12	39	39	1,00	26	31	0,84
13	38	32	1,19	28	22	1,27
14	24	13	1,85	21	10	2,10
15	6	7	0,86	4	4	1,00
16	24	19	1,26	22	18	1,22
17	53	35	1,51	47	34	1,38
18	76	67	1,13	72	64	1,13
19	69	55	1,25	54	45	1,20
20	53	45	1,18	49	40	1,23
21	28	15	1,87	24	14	1,71
22	59	61	0,97	49	51	0,96
23	15	9	1,67	12	8	1,50
24	55	51	1,08	48	45	1,07
25	35	31	1,13	27	23	1,17
26	6	5	1,20	4	2	2,00
27	56	64	0,88	48	54	0,89
28	9	4	2,25	8	4	2,00
$\bar{x}$			1,28			1,35
SD			0,38			0,41
$t = (\bar{x}-1)/(SD/\sqrt{28})$			3,80			4,43
P			<0,001			<0,001

TABLE 2. The results of the comparison of membrane filters (WL).

MFC agar (Difco)
G = GELMAN GN-6, S = SYNPOR

Sample no	volume per plate, ml	Filter	Number of typical colonies per plate 10 plates per sample	$\bar{x}$	SD
1	100	G	88 104 104 88 91 70 77 98 86 87	89,3	9,5
		S	75 106 95 85 106 81 90 87 85 79	88, 9	9,4
2	10	G	13 13 5 13 14 9 17 13 17 11	12,5	3,5
		S	11 12 20 17 11 15 20 11 13 8	13,8	3,7
3	100	G	2 0 3 1 0 2 2 1 2 1	1,4	1,2
		S	1 1 2 2 0 2 3 3 4 2	2,0	1,4
4	100	G	2 3 7 10 11 5 7 8 10 7	7,0	2,7
		S	6 9 12 12 4 4 7 4 7 5	7,0	2,7
5	1	G	17 30 23 19 18 26 22 27 29 31	24,2	4,9
		S	28 30 23 24 30 21 16 34 25 30	26,1	5,1
6	20	G	1 1 4 4 1 0 3 1 6 4	2,5	1,6
		S	1 3 0 5 2 7 2 1 1 1	2,3	1,5
7	100	G	14 18 21 16 20 18 19 20 17 18	18,1 *)	4,3
		S	10 15 12 5 10 24 15 16 13 13	13,3 *)	3,7
8	100	G	56 58 60 63 77 63 68 60 67 62	63,4	8,0
		S	49 70 70 68 69 67 76 71 66 82	68,8	8,3
9	20	G	40 55 46 39 47 40 33 42 52 44	43,8	6,6
		S	39 31 54 33 30 39 45 40 35 36	38,2	6,2
10	2	G	37 55 33 57 47 44 50 50 48 55	47,6	6,9
		S	30 44 45 41 49 44 38 44 48 52	43,5	6,6

Standard deviation is estimated according to the Poisson distribution

*) difference statistically significant at the 5 % level

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PHYTOBENTHOS AS AN INDICATOR OF THE DEGREE OF POLLUTION IN THE GULF OF FINLAND AND IN NEIGHBOURING SEA AREAS

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A SURVEY OF RESEARCH ON PHYTOBENTHOS IN THE COASTAL WATERS OF THE SOVIET BALTIC

The first known work on the benthic algae of the southern coast of the Gulf of Finland dates from 1805. In his report on the summer expedition made by students in 1803, Prof. Germann recorded the first reports of the algae *Fucus vesiculosus* and *Ulva (Enteromorpha) intestinalis*, found on the shore between Utria and Narva. Germann (1805) wrote about Narva Bay "that at its best there was nothing else but bladderwrack to be found". In the same year the species *Fucus vesiculosus* was mentioned also by Friebe (1805). A few decades passed and Postels and Ruprecht (1840), after having participated in Admiral Lütke's (Litke) voyage around the world, published data on seven species of algae collected from the Gulf of Finland and the Baltic Sea: *Fucus vesiculosus* L., *Desmarestia viridis* Lamour. = *Dichloria viridis* (Müll.) Grev., *Scytosiphon erectus* Lyngb. = *Enteromorpha flexuosa* ssp. *paradoxa* (Dillw.) Bliding, *Gigartina plicata* Lamour. = *Ahnfeltia plicata* (Huds.) Fries, *Ceramium diaphanum* (Lightf.) Roth, *Conferva fracta* Fl. Dan. = *Cladophora fracta* (Vahl ex Fl. Dan.) Kütz., *Enteromorpha intestinalis* (L.) Link. The authors pointed out that the Baltic Sea was poor in algae,

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while at the same time very little investigated. Luce (1823), Heugel (1847, 1851/52) and Müller (1849, 1852/53) mentioned some charophytes in Haapsalu Bay and the frequent occurrence of *Fucus vesiculosus* in the Baltic Sea, including the coastal waters of northern Saarenmaa. The algae collected from the southern coast of the Gulf of Finland and from the Gulf of Riga were also recorded by Eichwald (1844, 1847, 1849, 1852). In a survey of the lower plants of the eastern Baltic countries, Dietrich (1856/59) gave information about five species of marine algae.

The first researcher whose data represent unavoidable comparative material for an algologist today, was Gobi (1874a, b; 1875a, b; 1877a, b, c; 1879a, b; 1880). Prior to his day, investigators had studied algae which were chiefly collected from shallow water, as well as seaweed cast up on the shore (Postels and Ruprecht being exceptions). Gobi collected his material from the sea using a special device designed for sampling from aboard a boat. His works of 1874 and 1877 are of particular interest as they contain data and observations on the ecology of algae (depth of occurrence, character of the bottom, water salinity), and on the geographical distribution of algal species from the whole Gulf of Finland. In his works of 1879 one can find information about changes in the algal flora from Sestroretsk right up to Tallinn, and repeated hints at the low salinity of the Gulf of Finland which accounts for the small number of real marine species and the frequent occurrence of dwarf forms there.

The first survey of the flora of the eastern Baltic countries and of the published literature was "Literatur- und Pflanzenverzeichnis der Flora Baltica" by Winkler (1877), which gave a review of the major part of the relative literature published since 1791.

Svedelius' comprehensive "Studier öfver Östersjöns hafsalgflora" (1901) appeared at the turn of the century, followed by "Hafsalger från Dagö" (1902) in which he described 17 algal species and forms collected from the shore of Hiiumaa Island in 1897.

Again several decades passed before new information about the phytobenthos of the north and north-western coasts of Estonia made its appearance. The materials of Häyrén (1930) date from 1924-1928. In addition to the list of species, he also mentioned some associations of brackish-water benthic algae. H. Skuja (1928) had described some interesting algal species from the geolittoral of the Vaika islands (western Saaremaa). Fromhold-Treu (1935-1936) described some marine macrophytes among the phanerogams inhabiting the small marine islets between Hiiumaa Island (Dagö) and the mainland. In 1936 a work by Lippmaa appeared which was not very bulky, but contained some thoroughly elaborated and well analysed material (the species had been determined by Häyrén and Cedercreutz). The groups of "haloenalides" and "halonereides" were distinguished, and the distribution of *Zostera marina* on the southern coast of the Gulf of Finland, on the coasts of West Estonia and its western islands was recorded. The algal flora of the western islands and the Väinameri was also dealt with in the floristic works of Eklund (1927-28, 1929) and Gröntved (1927, 1953). Häyrén (1930) described finds of marine algae in the surroundings of Tallinn, in the vicinity of Paldiski, on the coasts of Pakri and the western islands, and in 1936-37 the seaweed cast up on the shores of the western islands. In his work of 1940, Häyrén gave a survey of the phytobenthos of the coastal waters of Suursaari (Hogland) and the associations of the algae, differentiating seven associations. Data on the alg-flora of Vyborg Bay can be found in Herlin's work (1945). A paper by Pork (1954), devoted to the charophytes of the Estonian SSR, is worth mentioning. Besides the species occurring in fresh water, the species inhabiting the Baltic Sea were also dealt with. The stores of the red algae valuable from the industrial point of view were investigated by Kireyeva (Киреева 1961, 1964 and others).

Beginning in 1959, the Baltic Sea and the Gulf of Finland have been continuously studied by the Marine Ichthyological Laboratory of the Institute of Zoology and Botany, the Estonian SSR Academy of Sciences (now the Tallinn Department of the Baltic Fishery Research Institute). The research work was begun in the Riga Bay and Väinameri area (T. Trei-Pullisaar), and since 1970 has been carried out in the waters along the southern coast of the Gulf of Finland (H. Kukk). Since 1976, studies on the phytobenthos have been conducted also in the Department of Marine Biology of the Institute of Zoology and Botany (T. Trei).

These studies have mainly centred on two aims: 1) to obtain information about the distribution and ecology of species, and to differentiate plant communities; 2) to assess the stocks ofeconomically utilizable species and the prospects for their exploitation. During the last decade these investigations have also been associated with studies on the effects of human activity on the phytobenthos. During the first years the material was collected (together with the zoobenthos) using some special mechanical equipment. In 1961 SCUBA divers joined the work, and since 1966 samples have mainly been collected in collaboration with them. The research workers themselves have dived as well. The following papers have been published on the phytobenthos of the above-mentioned area: Pullisaar 1961; Trei 1964, 1965, 1968, 1970a, b, 1973, 1975, 1978, 1981; Трей 1973, 1976, 1977, 1982a, b, 1983; Kukk 1973, 1980, 1981; Кукк 1977, 1978a, b, c, 1979a, b, c, 1980a, b, 1982a, b, 1983; Кукк Э. Т., Кукк Х. А. 1976; Кукк Х., Пыдер 1978; Veldre et al. 1981, 1984; Irha et al. 1983; Ирха, Кукк 1983.

FLORISTIC COMPOSITION, ENVIRONMENTAL FACTORS AND DISTRIBUTION OF THE PHYTOBENTHOS. INDICATIVE VALUE OF SOME SPECIES

The macrophytobenthos mainly consists of algae, representing green algae, charophytes, and brown and red algae. The share of phanerogams is smaller.

The phytobenthos of the Baltic Sea is characterized by a poor floristic composition.

A floristic list of the phytobenthos is given below (Table 1). The taxa were identified by T. Trei in West-Estonian coastal waters (Trei 1978; Трей 1976, 1977, 1983 and some unpublished data) and by H. Kukk in the Soviet waters of the Gulf of Finland

(Кукк 1978, 1979). The taxa are ranged according to Pankow (1971).

The distribution of the phytobenthos depends on several environmental factors.

The vertical distribution is connected with the transmission of light through the water column. This depends on the quantity of seston in the water. In the open coastal waters of West Estonia, and at the entrance to the Gulf of Finland, the phytobenthos extends to a depth of 18-20 m. In the bays in West Estonia and in the middle part of the Gulf of Finland it reaches 10-15 m, and in the eastern part only down to a depth of 6 m (Кукк 1980). In some areas the absence of suitable substrates determines the lower distribution limit of the phytobenthos.

Table 1. Floristic list of the phytobenthos and the indicative value of some species

Taxa	West-Estonian waters	The Gulf of Finland	The area evidently preferred by the species of: Undisturbed coastal waters	Moderately eutrophicated areas	Strongly eutrophicated areas
1	2	3	4	5	6
Green algae					
Ulothrix zonata (Weber et Mohr) Kütz.		+			
Ulothrix tenerrima Kütz.		+			
Ulothrix subflaccida Wille	+	+			
Ulothrix spp.	+			------------	
Geminella sp.	+			------------	
Capsosiphon fulvescens (C.A.Ag.) Setchell et Gardner	+				
Percursaria percursa (C.A.Ag.) Bory	+				
Ulvopsis grevillei (Thuret) Gayral = (?) *Monostroma balticum* (Aresch.) Wittr.	+		------------	------------	
Enteromorpha intestinalis L.	+	+			
Enteromorpha prolifera (Müller) J.Ag.	+	+			
Enteromorpha ahlneriana Bliding	+	+			
Enteromorpha pilifera Kütz.	+	+			
Prasiola stipitata Suhr in Jensen	+				
Rosenvingiella polyrhiza (Rosenv.) Silva	+				
Stigeoclonium protensum (Dillw.) Kütz.	+				
Stigeoclonium tenue (Ag.) Kütz.	+				
Chaetomorpha capillaris (Kütz.) Börg.	+?	+			
Chaetomorpha linum (Müller) Kütz.	+		------------		
Rhizoclonium riparium (Roth) Harvey	+	+			
Rhizoclonium implexum (Dillw.) Kütz.	+	+			
Cladophora aegagropila (L.) Rabenh.	+	+			
Cladophora rupestris (L.) Kütz.	+	+			
Cladophora oblitterata Söderstr.	+				
Cladophora glomerata (L.) Kütz.	+	+		------------	----------
Cladophora sericea (Huds.) Kütz. sensu van Hoek	+				
Cladophora albida (Huds.) Kütz.	+		------------		
Oedogonium spp.	+				
Urospora penicilliformis (Roth) Aresch.	+	+			
Spirogyra spp.	+	+			
Zygnema spp.	+				
Mougeotia spp.	+				

1	2	3	4	5	6
Charophytes					
Tolypella nidifica (Müller) Leonh.	+	+			
Chara canescens Loisel.	+				
Chara tomentosa L.	+				
Chara contraria A.Br. ex Kütz.	+				
Chara baltica Bruz.	+				
Chara aspera Deth. ex Wild.	+	+			
Chara connivens Salzm. ex. A.Br.	+				
Brown algae					
Pilayella littoralis (Lyngb.) Kjellm.	+	+			
Ectocarpus confervoides (Roth) Le Jolis	+	+			
	s.lat.sensu Kjellm.	f.confervoides			
Sphacelaria radicans (Dillw.) C.A.Ag.	+				
Sphacelaria arctica Harvey f. arctica	+	+			
f. plumigera (Holmes) Pankow	+				
Pseudolithoderma subextensum (Waern) Lund	+	+			
Pleurocladia lacustris A.Br.		+			
Elachista fucicola (Velley) Aresch.	+	+			
Leathesia difformis (L.) Aresch.	+	+			
Cladosiphon zosterae (J.Ag.) Kylin		+			
Stictyosiphon tortilis (Rupr.) Reinke	+	+			
Dictyosiphon foeniculaceus (Huds.) Grev.	+	+			
f. foeniculaceus					
f. hippuroides (Lyngb.) Levring	+	+			
Dictyosiphon chordaria (Aresch.) Du Rietz		+			
Chorda filum (L.) Stackh.	+	+			
Chorda tomentosa Lyngb.		+			
Fucus vesiculosus f. vesiculosus	+	+			
f. plicata Kjellm.	+	+			
f. nana C.A.Ag.	+	+			
f. angustifolia C.A.Ag.	+	+			
f. filiformis C.A.Ag.	+				
Red algae					
Asterocytis ornata (C.A.Ag.) Hamel[x]	+	+			
Rhodochorton purpureum (Lightf.) Rosenv.	+				
Polyides rotundus (Huds.) Grev.	+	+			
Hildenbrandia prototypus Nardo	+	+			
Harveyella mirabilis (Reinsch) Reinke et Schmitz	+				

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[x] = Chroodactylon ramosum (Thwait.) Hansg.

1	2	3	4	5	6
Furcellaria lumbricalis (Huds.) Lamour.	+	+	/\/\/\/\		
f. lumbricalis					
non-attached form	+		- - - - - -		
Phyllophora truncata (Pallas) Newroth et Taylor f. truncata	+	+	- - - - - -		
f. elongata	+	+			
f. angustissima	+	+	/\/\/\/\		
Ceramium rubrum (Huds.) C.A.Ag.	+	+	- - - - - -		
Ceramium tenuicorne (Kütz.) Waern	+	+	———— - - - - - -	————	
Callithamnion roseum (Roth) Harvey	+				
Callithamnion sp.		+			
Polysiphonia nigrescens (Smith.) Grev.	+	+	———— - - - - - -	- - - - - -	
Polysiphonia violacea (Roth) Grev.		+			
Polysiphonia atro-rubescens (Dillw.) Grev.	+				
Rhodomela confervoides (Huds.) Silva f. tenuior	+	+	/\/\/\/\		
Phanerogams					
Ranunculus baudotii Godr.	+	+			
Ranunculus circinatus Sibth.	+				
Ceratohyllum demersum L.	+				- - - - - -
Myriophyllum spicatum L.	+	+		/\/\/\/\	
Zostera marina L.	+	+	/\/\/\/\		
Potamogeton filiformis Pers.	+	+	————	————	
Potamogeton pectinatus L.	+	+	————	————	
Potamogeton lucens L.	+	+			
Potamogeton perfoliatus L.	+	+	/\/\/\/\		
Ruppia cirrhosa (Petagna) Grande	+		- - - - - -		
Ruppia maritima L.	+	+	————		
Zannichellia palustris L.	+	+	/\/\/\/\	/\/\/\/\	
Najas marina L.	+				
Schoenoplectus lacustris (L.) Palla	+				
Schoenoplectus tabernaemontanii (C.Ch.Gmel.) Palla	+	+			
Bolboschoenus maritimus (L.) Palla	+				
Phragmites australis (Gav.) Trin. ex Stoud.	+	+		/\/\/\/\	/\/\/\/\

The following denotations are used:

/\/\/\/\ common views of H. Kukk and T. Trei

———— according to H. Kukk, based on data collected from the Gulf of Finland

- - - - - - according to T. Trei, based on data collected from West-Estonian waters

As a rule green algae, charophytes and phanerogams occupy shallow coastal areas. Brown algae also inhabit deeper points, and red algae occur in the deepest areas. Some individual species deviate from this rule.

Marine green, brown and red algae obtain their nutrients from the water, the substrate only constituting a place for attachment. Charophytes and phanerogams inhabit sediment bottom (sand, clay, mud) in sheltered or isolated sea areas. Owing to wave activity in exposed areas, sandy bottoms are often compeletely void of vegetation. In exposed localities on hard bottoms the wave action can also affect the vegetation, tearing off the algae from the substrate and preventing their spores from settling. At the same time a high degree of water movement increases the nutrient supply of the algae (Wallentinus 1976). The tides in the Baltic are insignificant, but the water movement caused by the wind, is quite significant in some localities.

The salinity is the most important environmental factor affecting the horizontal distribution of the phytobenthos in the study area. Many species encounter their salinity tolerance limit in the Gulf of Finland. At the entrance to the Gulf of Finland the salinity is about 7 °/₀₀, while in Neva Bay it does not exceed 1 °/₀₀. The reduction in the number of species of algae, running from west to east, is shown in Table 2.

The decrease in the salinity influences the morphology and reproduction of marine algae, resulting in dwarf forms without sexual reproduction. Only sterile individuals were observed in the eastern and north-eastern and north-eastern parts of the Gulf of Finland. In addition, the water temperature, ice cover and the nutrient level influence the phytobenthos.

In recent decades there have been clear signs of the eutrophication of coastal waters.

Table 2 (drawn up by H. Kukk). Number of green, brown and red algal species in different parts of the Gulf of Finland

		Green algae		Brown algae		Red algae	
	Number of species	Number	Percentage	Number	Percentage	Number	Percentage
Western part of the Gulf	28	5	18	14	50	9	32
Middle part of the Gulf	23	6	26	13	57	4	17
Narva Bay	15	6	40	8	53	1	7
Luga Bay	14	7	50	6	43	1	7
Neva Bay	8	5	63	2	25	1	12

For addition, the discharge of toxic and non-toxic substances and thermal pollution has caused extermination of the vegetation in the inner parts of several bays.

The coastal waters of the Gulf of Finland mainly suffer from the discharge of sewage and industrial waste water (especially the oil-shale and chemical industry, and paper-mills), which is often directly toxic to organisms.

The coastal areas of West Estonia are chiefly polluted by non-toxic sewage and waste water produced by the foodstuff industry. The pollution caused by agriculture and cattle-breeding also deserves attention. It is very often difficult to differentiate between the influence of pollution or eutrophication and that of low salinity.

The indicative value of some species is given in Table 1.

A SURVEY OF MARINE VEGETATION

a. Some theoretical principles in differentiating marine plant communities (phytocoenoses)

Most of the marine botanists consider that the terrestrial communities and the communities of macrophytobenthos are so similar that the same analytical methods can be used for studying both of them.

The concept of phytocoenosis formulated by Sukachev (1957) for terrestrial plant communities is valid also in the case of water plant communities. A phytocoenosis is considered to be any group of plants which is to a certain extent uniform in its composition and structure, being characterized by the uniformity of the mutual relationships between the plants and the relationships between the plants and their environment.

Two essential features of plant communities formulated by Lippmaa (1933); 1) the historical formation and 2) the cohabitation of species with a more or less similar ecology, can be attributed to sea phytocoenoses as well.

The struggle for survival, for light and space also takes place on the sea bottom (Kornaś et al. 1960). The marine plants shade the light from each other, and it is vital for them to find room on the sea bottom. At the same time they shelter each other from the destructive activity of the waves. Some species can exist only when sheltered by larger ones.

Like terrestrial vegetation, those marine plant communities which have the same dominating species, floristic composition, structure and ecological requirements, can be regarded as one and the same association.

We concur very much with the idea of den Hartog and Segal (1964) that, in aquatic plant communities, the dominating species are more valuable indicators than the common floristic composition, which is the case with terrestrial communities.

Due to the fact that the aquatic environment is relatively homogeneous, the floristic composition of the communities is more uniform. There are only a few aquatic plant species that are characteristic of a single association. The same species very often occur with a high constancy in several associations. Aquatic plant species have their optimum in the particular ecological conditions where they are dominant, although they are also quite tolerant of less optimal conditions.

We also support the standpoint of the above-mentioned authors in that communities of different substrates are separate from and independent of each other, although they can be found side by side. For example, in places where isolated boulders are lying on a sandy bottom, different associations develop on these substrates, in spite of the general impression of a homogeneously mixed vegetation of rhizophytes and haptophytes. We are of the opinion that, in accordance with the above-mentioned idea, it is possible to differentiate between associations even on a bottom where scattered pebbles occur on sand.

Although marine plant communities can often be damaged by stroms and by the mobility of the stones which form their substrate, they regenerate again in the same place in the same floristic composition. Professor H. Pankow (Очерки 1984) has expressed the idea that a concrete complex of ecological factors causes the formation of communities in such a way that essential changes in floristic composition are excluded.

b. Study methods

The depth and transparency of the water were measured at every station using a Secchi disc. The salinity was also determined. The character of bottom sediments, the height of stands and the coverage of the bottom by plants were estimated by SCUBA divers. A sample of plants within a frame with a surface area of 0.25 or 0.1 m^2 (in some communities) was collected and fixed in 4 %-formaline. Identification of the species and weighing of the samples were made afterwards in the laboratory. The constancy of species in the samples was calculated. The wet biomass (i.e. phytomass) per 1 m^2 was calculated taking into consideration the coverage at the stations. This enabled us to get some idea about the quantity of vegetation on the sea bottom, although the method is rather inexact.

c. Characterization and classification of the associations of marine plants in the study area

The associations of marine plants were differentiated on the basis of dominant species and ecological requirements. The general floristic composition and the constancy of species was also taken into account. The numeral data for the associations are given in Table 2.

The associations were characterized by a poor floristic composition. The number of species in a sample usually did not exceed 10. The average number of plant species in the samples varied from 4.5 to 10. Monodominant associations prevailed. Four associations with two dominating species, and one association with three dominating species, were distinguished.

The structure of the communities was simple, the dominant species forming a dense or sparse layer in which the other species had a quantitatively insignificant role. Only the association *Fucus vesiculosus - Furcellaria lumbricalis* was usually two-layered.

The occurrence of epiphytic algae was rather typical. Very often the same species were present as epiphytes and attached to hard substrate as well (e.g. Waern 1952).

The phytocoenoses characterized by abundant epiphytes or some other subdominant species were distinguished as variants of the associations.

In order to obtain a more comprehensive survey of the associations differentiated in the study area, they are arranged according to the scheme presented by Trei (Трей 1973) for the classification of plant communities in West Estonian waters. Taking into account our local environmental conditions, this scheme was drawn up on the basis of the zonation scheme of shore vegetation presented by Du Rietz (1932, 1950). On gently sloping seashores and in areas with soft bottoms the zonation of vegetation is either not clearly developed or is absent. On most of the shores studied the geolittoral and upper hydrolittoral zones are not developed at all. The lower hydrolittoral with *Enteromorpha* and *Cladophora* associations often becomes conspicuous. Most of the differentiated associations occur in the sublittoral.

The communities of green algae represent hydrolittoral associations. Brown and red algae form the associations on hard bottoms in the sublittoral. The associations of sublittoral sediment bottoms are formed by charophytes, phanerogams and loose-lying brown and red algae.

The associations can be divided into three groups according to their reaction to pollution:

1) The associations registered only in relatively clean undisturbed waters, far from the populated centres. The shores of these open sea areas are widely exposed to wave action. Water transparency is comparatively high, reaching 8-10 m in summer.

2) The associations primarily found in clean water, but which also occur in somewhat polluted water. Among them we can find:
a) associations with some differences in the floristic list or in the interrelationships between different taxa
b) associations without any special registered differences.

3) The associations which evidently favour:
a) moderate and
b) strong eutrophication.

PHYTOBENTHIC COMMUNITIES IN UNDISTURBED COASTAL WATERS

The association *Enteromorpha ahlneriana* inhabits stony bottoms in the hydrolittoral in West-Estonian waters far from pollution centres. In recent years this monodominant association appears to have disappeared from Pärnu Bay and the surroundings of Kihnu Island, where it was observed in the early 1960s.

<u>The association *Fucus vesiculosus - Furcellaria lumbricalis*.</u> In addition to the separate associations of *Fucus* and *Furcellaria*, a community containing both these species occurs on hard bottoms in the northern and north-western coastal waters of Hiiumaa and Vormsi Islands, and in the western part of the Gulf of Finland (Lohusalu peninsula and the island of Naissaar). The differences in ecological conditions between the localities of the *Furcellaria* association and those of the mixed community are relatively small.

The community was usually two-layered. One of these layers was usually discontinuous. In places *Furcellaria* did not form a lower layer at all, but grew on the tops of stones, *Fucus* being attached to the lower parts of stones. Here and there abundant epiphytes occurred on the dominant algae, *Elachista fucicola* often being found on *Fucus*.

In some places *Furcellaria* was covered with a dense growth of *Electra crustulenta* var. *baltica*, and therefore appeared to be grey in colour. *Pilayella littoralis* (K: 77.8 %), *Ceramium tenuicorne* (K: 72.2 %), *Polysiphonia nigrescens* (K: 72.2 %) and *Sphacelaria arctica* (K: 66.7 %) had a high constancy in the coastal waters of West Estonia.

In the Gulf of Finland *Ectocarpus confervoides* (K: 70 %) occurred instead of the two last-mentioned species.

<u>The association *Furcellaria lumbricalis* and its variants</u> have an extensive area of distribution in the lower sublittoral of the open sea areas of western Estonia, and in the western part of the Gulf of Finland (up to Tallinn Bay). The substrate consists of stones and to a lesser degree also of coarse gravel and Silurian limestone.

In an area 30 sq km large along the western shore of the Sõrve peninsula, the standing crop of *Furcellaria* was estimated to be 12 000 - 15 000 tons.

In addition to *Furcellaria*, the most constant species were *Polysiphonia nigrescens* (K: 92 %) and *Phyllophora truncata* f. *angustissima* (K: 74 %). In the area of the Sõrve peninsula, *Rhodomela confervoides* and *Ceramium rubrum* had a high constancy (K: 87.5 % and 75 % respectively), although they were rarely found in other areas. In the Gulf of Finland *Ceramium tenuicorne* (K: 80 %) and *Ectocarpus confervoides* (K: 60 %) were the most constant accompanying species.

Important subdominants were *Polysiphonia nigrescens*, *Ceramium rubrum* and *Rhodomela confervoides*. The variants of the association *Furcellaria lumbricalis* can be distinguished on the basis of these subdominants.

The association *Rhodomela confervoides* occurs in open areas on the western coast of Saaremaa and Hiiumaa Islands, and at the entrance to the Gulf of Finland on stones. It is not found east of Tallinn.

The most constant species were *Polysiphonia nigrescens* (K: 60 %) and *Furcellaria lumbricalis* (K: 50 %).

The association *Zostera marina* occurs in relatively sheltered sea areas on sandy bottoms in the coastal waters of West-Estonian islands, and in the western part of the Gulf of Finland. Single phytocoenoses have been recorded to the east - near Vergi Bay.

In addition to *Zostera*, *Potamogeton pectinatus* or *Potamogeton perfoliatus* sometimes occurred with a coverage of 15 - 30 % or even more.

More constant taxa in West-Estonian waters were *Ceramium tenuicorne (K: 60 %)*, *Phyllophora truncata* f. *angustissima* (K: 50 %) and *Potamogeton pectinatus* (K: 50 %). In the Gulf of Finland *Ectocarpus confervoides* and *Cladosiphon zosterae* had a high constancy (K: 60 % and 40 %, respectively). These two species often occurred abundantly.

A variant of the association *Zostera marina* that was rich in the loose-lying red algae *Furcellaria lumbricalis* and *Phyllophora truncata* f. *angustissima* was distinguished in the Väinameri (Moonsund) archipelago. This community was two-layered, the above-mentioned red algae occurring in the lower layer (Trei 1978).

The association *Ruppia maritima* inhabits sandy bottoms and bottoms where the sand is mixed with gravel. This association was recorded at the entrance to the Gulf of Finland and in the vicinity of Ruhnu Island in Riga Bay.

The more constant accompanying species were *Cladophora glomerata* (K: 50 %) and *Ceramium tenuicorne* (K: 40 %).

The association *Chara tomentosa* was recorded, but not throroughly studied in 1964, in the isolated and shallow Käiva Bay (southern coast of Hiiumaa Island).

This association was no longer found in 1976, presumably owing to increasing pollution. The association today exists in the small, shallow, sheltered, relatively undisturbed Bay of Rame (West Estonia), and in the eastern part of Matsalu Bay.

PHYTOBENTHIC COMMUNITIES INHABITING CLEAN AND POLLUTED AREAS

a. The associations favouring clean water:

The association *Fucus vesiculosus*, and its epiphyte-rich variant, are extensively distributed on rocks, stones and flat limestone areas. In the open sea where the water transparency is good, the association can occur down to a depth of 8-9 m, elsewhere is extends to a depth of 5 m only. It is absent from the mouths of rivers and from the eastern part of the Gulf of Finland where the salinity of the water is lower than 4.5 (5) °/₀₀.

The structure of the association was simple. *Fucus* predominated forming a dense growth.

The accompanying species with a high constancy in the Gulf of Finland were *Ectocarpus confervoides* (K: 62 %), *Elachista fucicola* (K: 60 %), *Pilayella littoralis* and *Ceramium tenuicorne* (K: 47 %). The communities occurring at points on the western shore of Saaremaa Island deeper than 3 m, were characterized by a high constancy of *Polysiphonia nigrescens* (K: 94.5 %).

An epiphyte-rich variant of the assosiation *Fucus vesiculosus* was distinguished at the end of the 1960s in relatively undisturbed parts of the open sea to the west of the islands of Saaremaa and Hiiumaa. In spite of the luxurious growth of the epiphytes *Elachista fucicola, Pilayella littoralis* and *Ectocarpus confervoides*, the *Fucus* stands were in good condition.

The most constant species were the epiphyte *Elachista fucicola* (K: 86.7 %), *Pilayella littoralis* (K: 100 %), *E. confervoides* (K: 73.4 %).

In polluted areas *Elachista fucicola* was no longer found growing on *Fucus*, and the amounts of the epiphyte algae *Pilayella* and *Ectocarpus* had greatly increased. *Fucus* individuals had become so overgrown by epiphytes that the metabolism of the *Fucus* plants had been reduced, and the plants were gradually dying. This is one of the reasons why the *Fucus* stands have declined in the strongly polluted inner areas of many bays.

The data collected in 1982 showed that *Cladophora glomerata* dominated together with *Fucus* at many stations in Riga Bay (surroundings of Kihnu Island), forming nearly a half of the biomass of the phytocoenoses. *Cladophora* was attached to *Fucus* or to stones superceding the latter.

It seems to be expedient to differentiate the *Cladophora glomerata* variant of the association *Fucus vesiculosus*. At the beginning of the 1960s the proportion of *Cladophora glomerata* was insignificant.

In some places near the water-line the association *Fucus vesiculosus* was replaced by the association *Cladophora glomerata* or *Enteromorpha intestinalis*.

In Estonian waters the declination of *Fucus* stands in parts of the open sea where there is no pollution from the land was not established. It must be pointed out, however, that no special investigations on this aspect have yet been undertaken.

The association *Furcellaria lumbricalis - Polysiphonia nigrescens - Ceramium tenuicorne* is a very characteristic algal community in the Gulf of Riga and in the Väinameri on stony bottoms.

The quantitative role of the three dominating species varied in different localities substantially. At some stations all three species occurred in nearly equal proportions, while in some other places one or two of these species dominated. Often one stone was covered by nearly pure stands of one species, e.g. of *Furcellaria lumbricalis*, and one or two other species dominated on the neighbouring stones. *Ceramium tenuicorne* can live as an epiphyte or attached to stones. In places the role of epiphytes is significant.

In addition to the three dominating species, *Phyllophora truncata f. angustissima, Sphacelaria arctica* and *Cladophora glomerata* occurred with a relatively high constancy, although the actual value varied in different areas. For instance, the most constant accompanying species in the western part of Matsalu Bay was *Phyllophora* (K: 93.2 % in 15 samples), while *Sphacelaria* and *Cladophora* had a high constancy in Pärnu Bay and in the surroundings of Kihnu Island (66.6 % and 60 % respectively in 15 samples).

The association avoids strongly polluted areas. In conditions of moderate pollution (the middle part of Pärnu Bay) only fragments of this association occurred with a coverage less than 5 % and a biomass under 3 g/m^2. The high seston concentration in the water of Pärnu Bay presumably causes poor light conditions, and the deposition of seston on the algae hinders their metabolic activity.

The association occurred with a high coverage and biomass (610 g/m^2 (n=15)) in the weakly eutrophicated western part of Matsalu Bay. It is also remarkable that the role of *Polysiphonia nigrescens* is more significant there than in other areas, and has increased during the last decades. This alga has become a dominating species among *Furcellaria* and *Ceramium* in this area.

The association *Chara aspera* is very common in the relatively sheltered areas of western Estonia. In the Gulf of Finland it occurs quite rarely, in smaller patches with an average coverage of about 30 % and has been recorded eastward of Narva Bay (Кукк 1978). The association inhabits sediment bottoms (mud, clay, muddy sand, sand). A higher, but discontinuous layer of *Potamogeton* was sometimes distinguished.

A variant of *Chara aspera* rich in *Cladophora glomerata* was distinguished in some eutrophicated bays of the Väinameri and in the surroundings of Kihnu Island. This community was characterized by a high coverage and biomass. In Matsalu Bay in 1977 the coverage of this community was usually over 80 %, and the average biomass 837 g/m^2 (21 measurements). At the beginning of the 1960s a very significant subdominant in addition to *Cladophora glomerata* was *Rhizoclonium riparium*. In the course of the last few decades the role of *Cladophora glomerata* has substantially increased and this species has become a single subdominant. *Rh. riparium* occurs often, but not abundantly. *Rhizoclonium implexum* was recorded quite frequently.

The decline of the *Chara aspera*-association in conditions of strong pollution was established. The *Chara aspera*-association was the most wide-spread community in Haapsalu Bay in 1961-1962. The coverage of this community was 80-90 % over large areas. By the end of the 1970s, however, only fragments of this association occurred in a limited area or single scattered specimens found here and there. Such a trend was also observed in Pärnu Bay.

In somewhat polluted areas of the Gulf of Finland the blue-green algae were found to be additional species.

The association *Potamogeton filiformis* is distributed on sandy bottoms in sheltered inlets throughout the whole Gulf of Finland, avoiding the strongly polluted areas of Tallinn, Muuga, Ihasalu, Narva and Neva Bays (Кукк 1978, 1980).

The constancy of all accompanying species was low and did not exceed 30 %. In clean water the epiphytes *Leathesia difformis* and *Cladosiphon zosterae* were found attached to *Potamogeton*. *Ectocarpus confervoides* and *Pilayella littoralis* were additional species in the case of moderate pollution.

The association *Potamogeton pectinatus* is distributed throughout the whole area in relatively sheltered localities on sandy and muddy sandy bottoms in the form of scattered patches.

In the Gulf of Finland the dominant species was often accompanied by the epiphytic algae *Leathesia difformis*, *Cladosiphon zosterae*, *Pilayella littoralis* and *Ectocarpus confervoides*. Sometimes *Potamogeton filiformis* and *Zannichellia palustris* occurred, but their constancy did not exceed 30 %.

In 10 samples taken in West-Estonian waters in the surroundings of Kihnu Island the following species had a higher constancy: *Tolypella nidifica* (K: 90 %), *Ceramium tenuicorne* and

Cladophora glomerata (K: 70 %), *Myriophyllum spicatum* (K: 60 %).

In the Gulf of Finland this association is considered to be a clean water association (Кукк 1978). In West-Estonian waters *Potamogeton pectinatus* seems to be quite indifferent to moderate pollution. It has been recorded even in the polysaprobic zone of Haapsalu and Kuressaare Bays, and in relatively clean water as well. A variant of the *Potamogeton pectinatus*-association rich in epiphytes was distinguished. *Potamogeton* bore a dense growth of epiphytic algae, the floristic composition of which varied in different levels of pollution. The main dominant among epiphytes in the polysaprobic zone was *Lyngbya aestuarii*. In the mesosaprobic zone *Pilayella littoralis* and *Gloeotrichia pisum* dominated. The coverage in these phytocoenoses varied from 75 - 100 %, the average biomass being 1 048 g/m^2 (7 measurements). Nevertheless, heavy pollution in the area affected by the inflow of waste water in Haapsalu Bay had caused the destruction of this community. The area was still without vegetation also in 1978 and 1979 (Trei 1981).

Changes in the floristic composition and a decrease in the biomass and coverage were found in Kuressaare Bay in 1978 compared to the situation is 1976 (Trei 1985).

The association *Potamogeton perfoliatus* is distributed on sediment bottoms in the sheltered parts of bays throughout the whole area. This community mainly occurs in small patches only, not exceeding tens of square metres.

In West-Estonian waters only *C. glomerata* occurred with a relatively high constancy (K: 60 %). All accompanying species occurred in the Gulf of Finland with a constancy of less than 30 %.

The main distribution area of this association is in clean water (Кукк 1978). It avoids the shallow inner parts of several bays, occurring only in their outer parts. Nevertheless, there are some phytocoenoses in conditions of strong eutrophication in the shallow eastern part of Matsalu Bay. The abundant growth of *Cladophora glomerata* makes these communities different from the others.

The association *Zannichellia palustris* occurs on sandy and muddy sandy bottoms, sometimes on coarse gravel in the sheltered parts of the bays along the Gulf of Finland and in the coastal waters of western Estonia. In the last-mentioned area the association occurs mostly in small patches. In places it is accompanied by abundant *Potamogeton pectinatus*, which forms a higher, but discontinuous layer with a maximum height of 150 cm.

The more constant accompanying species were *Ectocarpus confervoides* and *Pilayella littoralis* (K: 40 %). In some places in the Gulf of Finland the epiphytes *Cladosiphon zosterae* and *Leathesia difformis* were found abundantly on *Zannichellia palustris* and *Potamogeton pectinatus*.

In conditions of eutrophication the floristic composition of the association had become more diverse. 14 taxa were recorded on muddy sand at a depth of 0.1 - 0.5 m in the shallow coastal water of Kihnu Island. *Zannichellia* was densely overgrown with threads of *Cladophora glomerata*. Frequently occurred *Rhizoclonium implexum*, *Ulothrix* sp., *Lyngbya aestuarii*, *Geminella* sp., *Oedogonium* sp. and *Spirogyra* sp.

The association of the loose-lying red algae *Furcellaria lumbricalis* and *Phyllophora truncata* f. *angustissima* is distributed on sediment bottom throughout Kassari Bay in the Väinameri over an area of about 140 sq km.

The association has a very distinctive physiognomy. The thalli of the algae lying entangled in masses on the sea bottom form an algal layer with a thickness of 5-15 cm. Patches without plants occurred in places. The total biomass of these algae was about 140 000 tons. The *Furcellaria* occurring in the algal layer have a shape which is more of less intermediate between that of the attached form of F. *lumbricalis* and that of the unattached F. *aegagropila*. The thalli lack organs for attachment and reproduction characteristic of F. *fastigiata*. The radial symmetry found in F. *aegagropila* is also missing. It is quite natural that, under such conditions, no radial symmetry can develop in the entangled algal layer. The average length of the thallus is 4 - 4.5 cm and the average diameter 0.5 - 0.8 mm. The branching of the thalli is mainly irregular, although dichotomic branching occurs quite often. The specimens of *Phyllophora* have narrow delicate thalli with a diameter varying between 0.5 and 1 mm. The length can reach 6.6 cm, although most of them are 3 - 5 cm long.

The role of these two algae is different in different parts of the algal layer. Thus, the area of pure *Furcellaria* or a mixture of algae containing 20 % *Phyllophora* covered 33 sq km. The average biomass was 1 006 g/m^2 (608 samples) and the total biomass about 33 000 tons gross weight (data for 1974) (Trei 1978). These algae form the basis of estagar production. Estagar has been produced since 1967.

In addition to the two dominant species mentioned above, 13 taxa of other species were recorded. These algae lay loose in the algal layer, attaching themselves as epiphytes to other plants or to shells, most frequently *Mytilus*. The most frequent species were *Polysiphonia nigrescens* and *Sphacelaria arctica*. It is characteristic that the specimens in the algal layer were small and in most cases had no reproductive organs.

A decrease in the biomass of the named association since 1975, caused by changes in environmental conditions, has been established. The area has become eutrophicated, and the water transparency decreased. Oil pollution should not be overlooked either (Kukk 1981).

b. The following associations may occur both in relatively undisturbed areas and in polluted areas of the Gulf of Finland without revealing any established differences:

The association *Ectocarpus confervoides - Pilayella littoralis* occurs on the flat limestone bottom of the Bank of Hiiumadal (Nekmansgrund) and on stones in the surrounding area, as well as to a lesser degree in other areas of West Estonia. It also covers extensive areas at the entrance to the Gulf of Finland and in the central part of the gulf (Кукк 1978b).

The community has a very distinctive physiognomy and is very uniform throughout its distribution area. Tufts of *Ectocarpus confervoides* and *Pilayella littoralis* form a dense and uniform cover on the bottom, resembling greenish-brown cotton-wool, and are firmly attached to the bottom. On limestone outcrops the plant cover is 100 % almost constantly, but on stones the vegetation is rather sparse. Since the plants are always overgrown with a dense cover of diatoms, it is often very difficult to determine the larger algae. Sometimes *Fucus vesiculosus* occurs abundantly and forms the higher layer of vegetation, rising above the other algae to a height of 15-30 cm.

In addition to the dominating species, *Ceramium tenuicorne* also had a high constancy. It was 76.5 % in West-Estonian waters and 50 % in the Gulf of Finland. *Stictyosiphon tortilis* was a rather constant accompanying species (K: 52.9 %) in the Gulf of Finland.

The association *Sphacelaria arctica* is a very wide-spread community on hard bottoms in the deeper, open areas of Estonian waters. The association is not found deeper than 7 m in Narva Bay, presumably due to the low water transparency. The association is not found eastward of Koporye Bay (Кукк 1978b, 1980).

Besides limestone outcrops and boulders, small stones and mussels also serve as a substrate. In Narva Bay the algae even attach themselves to the compact loamy bottom.

The coverage and the biomass showed great variation. In West-Estonian waters the coverage rarely exceeded 40 %, often being less than 10 %. In some places in the middle part of the Gulf of Finland it reached 100 %. The biomass of this association was the lowest in West-Estonian waters, where it did not usually exceed 14 (max. 31) g/m^2. At 20 stations in the Gulf of Finland the biomass was less than 1 g/m^2, but in some places in the middle part of the gulf it reached 200 g/m^2. The average for the whole Gulf of Finland was 20 g/m^2 (45 measurements). Besides the algae, many individual specimens of *Mytilus* and *Balanus* and colonies of *Laomedea (Hydrozoa)* were recorded. A cover of *Electra crustulenta* was often found on stones and mussels.

In the Gulf of Finland *Ceramium tenuicorne* and *Pseudolithoderma subextensum* had the highest constancy, 40 % and 30 % respectively. In West-Estonian waters *Polysiphonia nigrescens* (K: 76 %) was the most constant accompanying species. Sometimes this alga can occur with a remarkable coverage.

The association *Pseudolithoderma subextensum* represents a community peculiar to stones in deep water. It does not occur in the eastern part of the Gulf of Finland (Кукк 1978b).

A few individuals of accompanying algae, with an insignificant biomass, occur above the crust-forming, dominating species.

In addition to *Pseudolithoderma*, the most constant accompanying species were *Pilayella littoralis* (K: 85 %), *Sphacelaria arctica* (K: 71 %), *Rhodomela confervoides* (K: 65 %). Individual specimens of *Laomedea (Hydrozoa)* were often also found.

PHYTOBENTHOS COMMUNITIES FAVOURING EUTROPHIC AREAS

a. The associations preferring moderate eutrophication:

The association *Enteromorpha prolifera* occurs throughout the whole area of the Gulf of Finland in relatively well-sheltered inlets, except for the strongly polluted regions of Tallinn, Muuga, Narva and Neva Bays (Кукк 1977, 1978). It also occurs in some parts of West-Estonian coastal waters, but it has not been thoroughly studied there. The association prefers areas with a inflow of domestic waste water.

The height of *Enteromorpha* stands extended to 30 cm in the thermally polluted part of Koporye Bay. The highest biomass (500 g/m^2) was recorded in spring and in the first half of the summer. Fluctuations in the water level often cause desiccation of the communities.

All accompanying species occurred with a low constancy (less than 10 %) and not abundantly.

The association *Cladophora glomerata*. In the Gulf of Finland, the association was found to grow everywhere on suitable hard substrates in moderately polluted areas, and in relatively clean coastal waters of the open sea islands, as well as in sheltered and exposed areas. Dense communities with a coverage of 80-100 % were found, as a rule, at a depth of 0-1 m. This association was absent in the most polluted areas of Tallinn, Muuga, Narva and Neva Bays (Кукк 1978). *Fucus vesiculosus* occurred among *Cladophora* meadows in the coastal waters of the island of Tütarsaar, and formed another discontinuous layer with a height of 25 cm. The largest biomass of about 800 g/m^2 was registered in June - July.

Fucus vesiculosus (K: 50 %), *Pilayella littoralis* and *Ectocarpus confervoides* (K: 40 %) occurred with a higher constancy.

In West-Estonian waters *Cladophora glomerata* is widely distributed in eutrophicated and somewhat sheltered sea areas, and occurs in great masses in shallow bays. This community is destroyed by heavy pollution. We have observed it in Haapsalu Bay near the outflow of the waste water from the town. *Cladophora glomerata* occurs in small quantities in the exposed, non-eutrophicated coastal waters of the above-mentioned area, and does not form separate communities.

The association *Cladophora sericea - Cladophora glomerata* was observed on stony bottoms in the surroundings of Kihnu Island and the neighbouring islets in Riga Bay.

The dominant algae grew interwoven and entangled, and it was difficult to differentiate them from each other.

In addition to the dominant species, *Ceramium tenuicorne* was recorded with a constancy of 50 %. Its biomass in one sample was also quite high. All the samples were characterized by a mass occurrence of diatoms.

Cladophora sericea was a single dominant on stones in the same places in the early 1960s.

The association *Potamogeton pectinatus - Zannichellia palustris* was recorded in 1979 on the muddy bottom in the shallow eastern part of Matsalu Bay.

The association had a very peculiar physiognomy. Stems of both dominant species were slender, more delicate, elongated and differed very much from the usual form. As a result of this, they were not upright, but lay entangled and interwoven on the bottom. It was difficult to identify these phanerogams, only the occurrence of some fruiting bodies making it possible.

In addition to the dominating species, *Cladophora glomerata* (K: 100 %), *Lyngbya aestuarii* and *Spirogyra* sp. (85.7 %), *Cladophora aegagropila, Chara aspera* and *Chara tomentosa* (57.1 %) also had a high constancy.

The occurrence of several fresh-water species, *Myriophyllum verticillatum, Fontinalis antipyretica, Lemna trisulca* and others was typical. Various species of blue-green algae were recorded.

An association of the loose-lying dwarf forms of *Fucus vesiculosus* was found in sheltered bays in the Archipelago of the Väinameri, and in some bays along the Gulf of Riga.

The unattached dwarf *Fucus* individuals, mainly *Fucus vesiculosus* f. *filiformis* and *Fucus vesiculosus* f. *nana*, formed a 5-7 cm high, loose layer on the bottom.

Besides the dominating dwarf forms of *Fucus*, the most constant species were *Rhizoclonium implexum* (K: 70 %), *Cladophora glomerata* (K: 60 % and *Potamogeton pectinatus*. Sometimes the last-mentioned species occurred abundantly.

This association seems to be a typical community of the mesosaprobic zone. An expansion of the distribution area of this association in Haapsalu Bay has been observed in the last decades. It has become the most wide-spread community there. This association is absent in strongly polluted areas.

Cladophora glomerata occurred abundantly in this community in the eutrophicated inlet in the surroundings of Kihnu Island. The other algae were densely entangled in the threads of *Cladophora*.

b. The associations preferring strongly eutrophic areas:

<u>The association *Ulothrix zonata*</u> occurs in the eastern part of the Gulf of Finland, in the coastal waters of the capes of Seraya Loshad, Uspensky, Dubrovsky and of Dalnaya Bay. It forms

nearly pure stands at a depth of 0-1.5 m, with salinity range of 2-5.1 °/₀₀, in the estuaries of brooks and rivers in the vicinity of pollution sources (Кукк 1980).

The biomass was higher in spring and in the first half of summer.

The constancy of accompanying species did not exceed 10 %.

The association *Enteromorpha intestinalis* is distributed in shallow and somewhat sheltered areas in the bays of West Estonia and along the whole southern coast of the Gulf of Finland. *Enteromorpha* occupies stones and the underwater parts of several harbour constructions (quays, breakwaters, etc.). The association occurs especially abundantly, and without any accompanying species, in the vicinity of settlements where domestic sewage flow into the sea. *Enteromorpha intestinalis* also favours thermal pollution. This species forms a luxurious uniform belt with a height up to 150 cm in Koporye Bay, owing to the effect of the cooling water from the power station. At the same time the association is extremely sensitive to chemical pollution (Кукк 1980).

The biomass was the highest in spring (600 g/m^2). As a result of fluctuations in the water level, part of the *Enteromorpha* belt becomes desiccated and dies.

There were only 5 taxa recorded in 32 samples from the Gulf of Finland, 1-5 taxa in one sample. All accompanying species were far from abundant, and occurred with a constancy less than 10 %.

Unlike the data given above the coastal waters of Kihnu Island (West Estonia) had communities of rich floristic composition. 17 taxa were identified in 2 samples, *Cladophora glomerata* and *Geminella* sp. being more numerous than the others.

The association *Schoenoplectus tabernaemontanii* was observed on muddy and sandy bottoms in sheltered inlets.

The most constant species apart from the dominant plant was *Cladophora glomerata* (K: 30 %) (Кукк 1978b, 1980).

The association *Phragmites australis* colonizes the estuaries of rivers and sheltered areas in the coastal sea, preferring strongly eutrophic areas. It occurs in shallow water, extending to a depth of 0.5 m on muddy and muddy-sand bottoms.

The coverage in strongly eutrophic areas was 70 - 100 %, the biomass being as high as several kilogrammes per sq metre.

Some threads of *Cladophora glomerata* and *Spirogyra* sp. and colonies of epiphytic blue-green algae were occasionally found on the stems of *Phragmites* in the Gulf of Finland (Кукк 1978b, 1980).

Table 3.

Phytobenthic communities in the Gulf of Finland (F) and West-Estonian coastal waters (W)

Association	Depth m	S °/₀₀	Height cm	Biomass g/m^2	Average g/m^2 (n)	Coverage %	Taxa in samples
Undisturbed waters							
Enteromorpha ahlneriana	0 - 0.5	0-7				80-100	
Fucus vesiculosus-Furcellaria lumbricalis	4 - 10	>5.8	30 - 40 7 - 10	90-1922	W 804(17) F 364(7)	60-100	20/31
Furcellaria lumbricalis	4 - 14	>5.8	5 - 10	18-1602	W 405(40) F 97(7)	30-100	17/50
Rhodomela confervoides	6 - 15	>5.5	6 - 15	22-576	120(13)	5-100	11/13
Zostera marina	2 - 6	>5.5	30 - 50	128-1000	W 334(9) F 180(5)	40-100	19/18
Ruppia maritima	0.5 - 1	>6.0	10 - 25	40-330	F 140(3)	50-60	11/3
Clean and polluted areas: Associations favouring clean water							
Fucus vesiculosus	8 - 9	>4.5	15 - 35		W 1345(18) F 1500(91)	(30)60-100	23/109
Fucus with epiphytes	0.3 - 9	7		316-3303	1300(8)	70-100	18/15
F. lumbric.-Polysiphonia nigr.-Ceramium tenuic.	2 - 10	5.0-7.2	<6 - 7	3-554		3-100	25/50
Chara aspera	0.1 - 3	0-7	2 - 6(10)		W 200(5)	10-90	15/12
F	0.1 - 1				F 80(5)		
Potamogeton filiformis	1 - 3.5	3.5-5.9	10 - 40	100-450	F 210(15)	30-60	9/15
P. pectinatus	0.7 - 3.5	0-7	30 - 150	F 30-300 W 20-1600	183(12) W 810(10)	F 30-70 W 10-100	F 10/12 W 18/10
P. perfoliatus	0.7 - 3.5	0.1-6	15 - 150	W 200-300 F 150-430	 F 220(9)	W 30-70 F 50-90	W 27/10
Zannichellia palustris	0.5 - 2.5		5 - 35	F 15-570	F 98(9)	40-90	12/9
loose-lying *Furcellaria-Phyllophora*	5 - 9	6.5	5 - 15		1000(608)	50-100	15/608

Association	Depth m	S °/∘∘	Height cm	Biomass g/m²	Average g/m² (n)	Coverage %	Taxa in samples
Associations both in relatively undisturbed and in polluted areas							
Ectocarpus confervoides-Pilayella littoralis	1 - 16	>5		6-290	W 153(9) F 60(22)	100	18/39
Sphacelaria arctica	5 - 18	>(4.3)6	2 - 5	W 8-31 F 1-200	F 20(45)	10-40	17/70
Pseudolithoderma	9 - 18	>4.5					7/18
Associations preferring moderate eutrophication							
Enteromorpha prolifera	0 - 0.5	3-6	5 - 20		F 120(13)	50-500	7/13
Cladophora glomerata	0 - 3(5)	4	15	15-800	F 180	10-100	11/58
C. sericea-C. glomerata	0 - 1.5	5.5-6		92-2200(4)		100	10/4
P. pectinatus-Z. palustris	0.6 - 0.9	0.1-0.3		59-1115	392(7)	60-100	22/7
dwarf *Fucus*	1.2 - 5.0	5	5 - 7	197-4784	1354(10)	30(50-100)	27/10
Associations preferring strongly eutrophic areas							
Ulothrix zonata	0 - 1.5	2-5.1	5 - 15	60-350	95	40-100	7/11
Enteromorpha intestinalis	0.5 - 0.8	2-7	8 - 25	10-600	150	60-100	5/32
Schoenoplectus tabern.	0.1 - 0.7	5	10 - 150	300-2500	700	60-100	8/37
Phragmites australis	0 - 0.5		100 - 250	several 10^3		70-100	4/53
Pot. pect. with epiphytes	1.5 - 1.9	6.25		393-1638	1048(7)	75-100	21/7

PHYTOBENTHOS INDICATING THE DEGREE OF POLLUTION IN THE SPECIAL AREAS STUDIED

There are some old data in the literature (Eichwald 1849, 1852; Гоби 1880; Арциховский 1905) which enables us to compare the floristic composition of the phytobenthos in some areas of Estonian coastal waters in the second half of the 19th century and today, and to determine the long-term changes in the phytobenthos in these areas.

The changes in the phytobenthos in Haapsalu, Kuressaare and Matsalu Bays have been dealt with in the papers of T. Trei (1984, 1985).

In the following we shall discuss the changes in the flora and vegetation of Pärnu Bay (investigated in 1979, 1980 and 1982) compared with the data collected in the early 1960s.

The changes have become more evident in the northern part of the bay, which is more isolated and where the effect of the industrial and domestic effluents flowing into the bay from the Pärnu River is stronger. The vegetation is suppressed above all by bad light conditions, the Secchi disc transparency of the water often being less than 1 m. The shading effect is caused by a high content of seston, mainly of bottom particles.

An increase in the area lacking vegetation was established in the northern part of the bay.

Low salinity is also an unsuitable ecological factor for some species, since they are more sensitive to pollution in conditions of low salinity. Species such as *Enteromorpha ahlneriana, Cladophora rupestris, Zygnema* sp., *Tolypella nidifica, Chara canescens, Chara tomentosa, Pilayella littoralis, Stictyosiphon tortilis, Asterocytis ornata, Myriophyllum spicatum, Ruppia maritima* no longer occur in the present floristic list. This may be partly due to the reason given above. Some habitats of *Chara aspera* have disappeared in the surroundings of the town of Pärnu. The red algae, *Phyllophora truncata* f. *angustissima* and *Ceramium tenuicorne*, were abundant and frequent in 1959-1962. Only scattered specimens of these species have been recorded at three stations in recent years. At the same time some new species have been encountered: *Lyngbya aestuarii*, some species of *Oscillatoria*, *Ulothrix* sp., *Geminella* sp., *Rhizoclonium implexum*, *Chaetomorpha* (?) *capillaris*, *Ranunculus baudotii*.

The abundance and the standing crop of *Cladophora glomerata* has increased markedly. It has become a dominant alga in shallow coastal waters. The accumulation of mud on the bottoms, obviously connected with intensive agriculture in the surroundings of Kihnu Island especially, has also taken place.

The only rare recordings of the species, as well as in low abundance, may of course be accidental. They may not occur in the samples. Nevertheless, general trends have definitely been established - a decrease in the number of species of charophytes, brown and red algae, and an increase in the number of species of blue-green algae. The green algae include species favouring pollution, as well as ones which decline in polluted conditions.

The changes in the phytobenthos in Tallinn Bay and in the surroundings of Hogland Island (Suursaari) will be considered in the following.

LONG-TERM CHANGES IN THE BOTTOM VEGETATION OF TALLINN BAY

Thanks to T. Trei (1982) it is now known that the first data on the bottom vegetation of Tallinn Bay were published in 1849 by a distinguished geopaleontologist and zoologist, E. Eichwald, in his book "Beitrag zur Infusorienkunde Russlands", the title of which did not arouse botanists' attention. The next papers on the bottom vegetation of Tallinn Bay did not appear for 20 years. This time the author was a well-known algologist, Professor Chr. Gobi (Гоби, 1874, 1875, 1877, 1879; Gobi, 1874, 1877) from St. Petersburg. For some species he presents their exact habitats, whereas for others he leaves it unmentioned. Chr. Gobi recorded 16 macrophyte taxa for Tallinn Bay. The next work on the Tallinn Bay bottom vegetation belongs to E. Häyrén (1929-1930), who describes 3 macrophyte taxa from the algae washed ashore.

The period up to the 1970s is characterized by a stagnation in the investigation of the bottom vegetation. This changed in 1975 when sampling was performed at 127 stations. Repeated samplings were performed in 1976 (Кукк 1978a, 1979b) and in 1978 (Кукк 1979c, 1982b). H. Kukk has described 9 taxa of brown algae, 8 taxa of red algae and 9 taxa of green algae for Tallinn Bay. In addition, 9 taxa of phanerogams have been established.

The studies revealed that the distribution area of the species *Fucus vesiculosus* L., *Chorda filum* (L.) Stackh. and *Ceramium disphanum* (=*C.tenuicorne* (Kütz.) Waern described by E. Eichwald (1849) has been reduced, and they have retreated offshore. *Polysiphonia nigrescens* (Smith) Grev. occurs in rare patches north of the Paljassaar peninsula and in the north-western coastal waters of the Viimsi peninsula (Кукк 1979b). For the time being *Chara fragilis* Desv. & Loisel. has disappeared from the bay. However, *Enteromorpha intestinalis* is as abundant (especially in the area of the discharge of municipal sewage) as it was in the middle of the 19th century. In addition to the latter, H. Häyrèn recorded *Cladophora glomerata* (L.) Kütz. and *Pilayella littoralis* (L.) Kjellm. in algae washed up on the shore in 1930. It is of interest that Chr. Gobi did not list *Pilayella littoralis* among macrophyte species of the Tallinn Bay, although they evidently still occurred there at that time as well as the species *Enteromorpha prolifera* (Müll.) J.Ag., *Rhizoclonium riparium* (Roth) Harv., *Cladophora aegagropila* (L.) Rabenh., *Phyllophora truncata* (Pallas) Newroth and Taylor, *Ph. truncata* (Pallas) Newroth and Taylor f. *angustissima* (Ag.) Sjöstedt, *Ceramium tenuicorne* (Kütz.) Waern and *Polysiphonia violacea* (Roth) Grev. Omission of these species from Chr. Gobi's papers might be due to the fact that the sampling was performed mechanically, and samples were not taken from all parts of Tallinn Bay. The addition of *Ulothrix subflaccida* Wille and *Urospora penicilliformis* (Roth) Aresch. nowadays to those registered by Chr. Gobi may be accounted for the impact of growing pollution.

At the present time the following species recorded by Chr. Gobi in Tallinn Bay are lacking: *Cladosiphon balticum* Gobi

(= *Dictyosiphon chordaria* (Aresch.) Du Rietz), *Mesogloia zosterae* Aresch. (= *Cladosiphon zosterae* (J.Ag.) Kylin), *Castagnea virescens* (Carm.) Thur. (= *Eudesme virescens* (Carm. in Hooker) J. Ag. and *Leathesia difformis* (L.) Aresch.

Similarly, bottom vegetation is now practically completely absent in the southern part of Tallinn Bay (Кукк 1978b, 1979b). *Ectocarpus confervoides* is absent from the Pirita area, i.e. in the southern coastal waters of Tallinn Bay (Кукк 1979b), where Chr. Gobi (1874; Гоби, 1879) described the species under the name of *E. approximatus* var. *balticus* Kütz. Even *Sphacelaria arctica*, which Chr. Gobi recorded as *S. racemosa* Grev. in the vicinity of Kadriorg (the southern tip of the bay), is now found only in the open parts of the bay. Chr. Gobi has listed the following species for the coastal waters of the Kadriorg area: *Elachista flaccida* Dillw. and *E. stellaris* Aresch. (= *E. fucicola* (Velley) Aresch.), *Chorda filum* (L.) Stackh., *Fucus vesiculosus* L., *Polysiphonia nigrescens* (Smith.) Grev. (Gobi 1874, 1877; Гоби 1874, 1875, 1879). At the present time these species no longer occur in this part of the bay (Кукк 1979b). *Stictyosiphon tortilis* (Rupr.) Reinke occurs only in the open part of the bay, in the coastal waters of the Aegna and Naissaar Islands. According to Gobi (Гоби 1874), however, *Dictyosiphon tortilis* Rupr. was abundant in the Tallinn Bay. *Enteromorpha procera* Ahlner. (= *E. ahlneriana* Bliding), which was recorded by Chr. Gobi for the Tallinn Bay, is now distributed only in the western and offshore coastal waters of the Aegna Island (Кукк 1978a, 1979b).

The investigations carried out by H. Kukk in 1983 show that the area of *Fucus vesiculosus* in Tallinn Bay has been considerably reduced since the species is replaced by *Cladophora glomerata* and *Ceramium tenuicorne*.

Since the discharge of municipal sewage is practically absent in the southern part of the Tallinn Bay, and this area is affected by waste waters form the cellulose and paper industry, which is difficult to decompose, even the representatives of microphytobenthos (Vilbaste 1982) and macrophytes (Кукк 1979b) are lacking.

Species such as *Urospora penicilliformis*, *Ulothrix zonata*, *U. subflaccida*, *Enteromorpha intestinalis*, *E. prolifera*, *Cladophora glomerata*, *Pilayella littoralis*, *Ectocarpus convervoides*, *Ceramium tenuicorne* (Кукк 1979a, b) occur in moderately polluted sea areas there.

Elachista fucicola, a typical epiphyte on *Fucus vesiculosus*, has been found to disappear already in slightly polluted areas. It is replaced by *Pilayella littoralis*. The increase in pollution is likely to be accompanied by an ever increasing abundance of epiphytes, and an increase in biomass. Finally, epiphytes cover *Fucus* so completely that the photosynthesis of the host plant is prevented and it dies (Kukk 1980; Кукк 1982b). This is followed by a decrease in the biomass since the association of *Fucus vesiculosus* has the highest biomass among the species characteristic of the Tallinn Bay. If in moderately polluted areas of Tallinn Bay one can meet 6 species of green algae, 2 species of brown algae and 1 species of red algae, then in its open part these figures are 6, 8 and 7, respectively (Кукк 1982b).

LONG-TERM CHANGES IN THE BOTTOM VEGETATION OF THE HOGLAND (SUURSAARI) ISLAND COASTAL WATERS

Hogland is a long (11 km) and relatively narrow (1.5-3 km) island lying in the northeastern part of the Gulf of Finland, The first data on the bottom vegetation in its coastal waters were obtained and presented by Chr. Gobi (1874, 1877), who studied samples collected mechanically and algae washed up on the shore in the eastern coastal waters of the island.

Chr. Gobi (1874, 1877) identified seven species of brown algae, two of which appear to be one and the same species: *Dictyosiphon chordaria* f. *baltica* Gobi = *Cladosiphon balticus* Gobi (= *Dictyosiphon chordaria* (Aresch.) Du Rietz), *Dictyosiphon foeniculaceus*, *Ectocarpus siliculosus*, *Pilayella littoralis*, *Ralfsia verrucosa* and *Dictyosiphon tortilis* (Rupr.) Gobi (= *Stictyosiphon tortilis* (Rupr.) Reinke). In addition to the above species, Chr. Gobi mentioned (in a footnote) two species of brown algae *Chorda filum* and *Eudesme virescens*, which he himself had not seen.

Chr. Gobi (1877) found three species of red algae: *Hildenbrandia rosea* (Kütz.) Gobi (= *Hildenbrandia prototypus* Nardo), *Ceramium gracillimum* Griff. et Harv. (= *C. tenuicorne* (Kütz.) Waern) and *Bangia fuscopurpurea* Ag.

In July 1939 the Finnish algologist E. Häyrén (1940) carried out studies on the bottom vegetation of the Hogland Island's eastern coastal sea (at 5 stations in its open part) and in the Suurkylä Bay. In addition to 5 species of blue-green algae, he recorded 9 species of green algae, 11 taxa of brown algae and 3 species of red algae. The next study on the bottom vegetation was carried out in 1976 by H. Kukk (Кукк 1979a, 1980a). New samples were collected in July 1983.

Since earlier investigators had confined themselves to studying the bottom vegetation mainly in the eastern and northeastern coastal waters of the island, an attempt was now made to survey the macrophytes in the Hogland's coastal sea as a whole. Samples were collected from 10 transects at 29 stations within a depth interval of 0-17 m. It was found that, as a rule, the vegetation did not spread down to a depth greater than 10 m, even when the bottom was stony and rocky. The recent results are compared to those obtained by earlier investigators in the following.

11 taxa of brown algae were determined.

1. *Pilayella littoralis* (L.) Kjellm. was recorded at 9 stations within a depth interval of 3-8 m. The plants had unilocular sporangia, and were attached to rocks and *Fucus*. They were frequent but not abundant throughout the whole study area.

It has earlier been described by Chr. Gobi (1874) and E. Häyrén (1940).

2. *Ectocarpus confervoides* (Roth) Le Jolis was found at 7 stations within a depth interval of 1-5 m. The species is common for the whole study area. E. Häyrén (1940) described it as a species of sparse distribution.

3. *Ectocarpus siliculosus* (Dillw.) Lyngb. was found once in Liivalahti attached to rocks at a depth of 3 m. The species occurs sparsely. Chr. Gobi (1874) found it in washed up algae along the eastern coast of the island. E. Häyrén (1940) described it as an abundant species in the inner part of Suurkylä Bay and offshore, as well as in Liivalahti and Kappellahti.

4. *Sphacelaria arctica* Harv. was found once on the southeastern coast to Hogland Island, attached to rocks at a depth of 8 m. E. Häyrén (1940) described the species under the name of *Sph. racemosa* Grev. offshore of Suurkylä Bay, where it occurred as a single specimen at a depth of 5 m.

5. *Pseudolithoderma subextensum* (Waern) Lund was found twice at depths of 5 and 8 m on the southeastern coast of the Hogland Island. Chr. Gobi (1874) described the species *Ralfsia verrucosa* on the eastern coast of the island which we, like E. Häyrén (1940), failed to find. E. Häyrén is convinced that it is actually *Lithoderma fatiscens* (= *Pseudolithoderma subextensum* (Waern) Lund), which Chr. Gobi took for *Ralfsia verrucosa*.

6. *Elachista fucicola* (Velley) Aresch. was recorded 4 times attached to *Fucus* at a depth of 1-3 m in the coastal waters of Liivalahti and Kiiskinkylä. According to E. Häyrén (1940), the species is abundant on *Fucus* offshore in Suurkylä Bay at a depth of 5 m, where we failed to find it. Besides, the plants we found occurred as sparse tufts on *Fucus*.

7. *Dictyosiphon foeniculaceus* (Huds.) Grev. f. *foeniculaceus* is frequent in the coastal waters of the island. The species was determined at 7 stations, where it occurred everywhere in coastal waters from the water level down to a depth of 5 m. Chr. Gobi (1874) recorded the species on the eastern coast. E. Häyrén (1940) recorded it in the vicinity of Suurkylä and in Liivalahti, where the species is of scattered distribution, as is the case nowadays.

8. *Dictyosiphon foeniculaceus* (Huds.) Grev. f. *hippuroides* (Lyngb.) Levring. Single specimens were found twice at a depth of 1-5 m in the vicinity of Kiiskinkylä, and in the coastal waters of the northwestern part of the island. E. Häyrén found

the taxa in Suurkylä Bay as far as Liivalahti, and they were abundant at that time. As for *D. chordaria* (Aresch.) Du Rietz, the only place in the Gulf of Finland where we managed to find it was in the vicinity of Vergi peninsula. The species was not abundant there (Кукк 1978a).

Chr. Gobi (1874) mentioned the species on the eastern coast of the island under the names of *Cladosiphon balticum* Gobi and *Dictyosiphon chordaria* (Aresch.) f. *baltica* Gobi. E. Häyrén recorded the latter in the environment of Suurkylä, Saunalahti and Liivalahti.

9. *Stictyosiphon tortilis* (Rupr.) Reinke was recorded at 6 stations. The species is of scattered distribution in the eastern and western coastal waters of the island at a depth of 3-5 m. Chr. Gobi (1874) mentioned massive occurrences of the species on washed up algae. E. Häyrén (1940) found it to be relatively abundant in the area stretching from Hirsikallio to Liivalahti.

10. *Fucus vesiculosus* L. f. *vesiculosus* is one of the most frequent taxa in the Hogland coastal waters. It was found at 10 stations at a depth of 1-8 m, both on the east and southeast coast. The species occurred as a dominant or a subdominant at almost all the stations. Chr. Gobi (1874) mentioned the species in the coastal waters of the island. However, he did not show its exact habitat.

11. *Fucus vesiculosus* L. f. *angustifolia* Ag. was recorded at 2 stations at a depth of 1 m in the island's southeastern coastal waters and in Kappellahti. In both cases it was not abundant. According to E. Häyrén (1940), the species appeared to be abundant in the vicinity of Hirsikallio, Suurkylä Bay and southwards - in Saunalahti. E. Häyrén did not confirm the occurrence of this form of the species in the Hogland coastal waters. We did not find the species, *Chorda filum* (L.) Stackh., which E. Häyrén (1940) found outside Suurkylä Bay at a depth of 5 m. Like E. Häyrén, we also failed to find *Eudesme virescens* (Carm. in Hooker) J. Ag. described by Chr. Gobi (1874).

RED ALGAE

1. *Chroodactylon ramosum* (Thwait.) Hansg. we found at one station scattered between the filaments of *Cladophora glomerata* at Liivalahti. The species has not been recorded earlier in Hogland coastal waters.

2. *Phyllophora truncata* (Pall.) Newroth et Taylor f. *angustissima* (Ag.) Sjöstedt was found only at one station at a depth of 10 m loosely in the western coastal waters near Kiiskinkylä. The species has not been recorded earlier.

3. *Ceramium tenuicorne* (Kütz.) Waern is one of the most frequent species at a depth of 1-5 m. It occurs throughout the length of the coastal zone, and was recorded at 10 stations in all. The vast majority of the plants had tetrasporangiums. The species is attached to rocks and as an epiphyte on *Cladophora rupestris*.

Chr. Gobi recorded the species under the name of *C. gracillimum* Griff. et Harv. on the eastern coast of Hogland Island, as well as an epiphyte on *Fucus* from Suurkylä Bay up to Liivalahti under the name of *C. diaphanum* Harv. (Häyrén 1940).

These were the only species of red algae we managed to find in the study area, although Chr. Gobi (1877) described the species *Bangia fuscopurpurea* (Dillw.) Lyngb. growing on *Stictyosiphon tortilis* on the eastern coast. In 1931 Prof. I. Välikangas found it abundantly on rocks of the eastern coast (Häyrén 1940).

Despite the efforts of skin divers we also failed to find *Hildenbrandia prototypus* Nardo which Chr. Gobi (1877) and E. Häyrén (1940) described as an abundant species.

GREEN ALGAE

1. *Enteromorpha intestinalis* (L.) Link was collected both in Suurkylä Bay as well as from the stones of a mole partly separating the bay from the open sea. It occurred there from the

water level down to a depth of 0.5-0.8 m,. The species was also found in Suurkylä Bay (near the cemetery) attached to larger stones on the sandy bottom. It was either a dominant or subdominant at all three stations.

According to E. Häyrén (1940), it occurred scattered among other species in the harbour of Suurkylä Bay.

2. *Enteromorpha prolifera* (Müll.) J. Ag. was found on the Suurkylä harbour quay down to a depth of 0.8 m. The species was not abundant. E. Häyrén recorded the species in Suurkylä harbour and in Hirsikallio as an abundant species under the names *Enteromorpha tubulosa* Kütz. f. *prolifera* (Fl. Dan.) and *E. crinita* (Roth) J. Ag. In addition to the above species, E. Häyrén recorded two more species *Enteromorpha hopkirkii* (M'Calla) J. Ag. and *E. clathrata* (Roth) J. Ag., which actually seem to be identical with the species *E. clathrata* (Roth) Grev. We did not find this species in Hogland coastal waters.

3. *Enteromorpha ahlneriana* Blid. was found on the side of the Suurkylä harbour quay facing the sea at a depth of 0.5 m. According to the literature, it has not been recorded earlier.

4. *Cladophora rupestris* (L.) Kütz. was recorded at 5 stations at a depth of 5-6 m. At a depth of 6 m it usually occurred as a subdominant in association with *Fucus vesiculosus*. Once at a depth of 5 m it appeared to form an independent frond and was overgrown by the epiphyte *Ceramium tenuicorne*. The species is distributed throughout Hoglands coastal waters. E. Häyrén (1940) recorded it at a depth of 5 m with a scattered distribution from Hirsikallio to the outer part of Suurkylä Bay.

5. *Cladophora glomerata* (L.) Kütz. is the most frequent species in the study area. It was found at 12 stations throughout the whole coastal sea from the water level down to a depth of 5 m. Within this depth interval it is often a dominant, and on three occasions it served as a dominant even at a depth of 5 m.

The species was earlier described by E. Häyrén (1940) as having a scattered to abundant distribution in the island's eastern coastal waters. In addition to this species, E. Häyrén (1940) has recorded *C. crystallina* (Roth) Kütz. which seems to be identical with *C. glomerata* (L.) Kütz., and the species *C. marina* Roth Hylmö which may be *Cladophora fracta* (Müll.) Kütz.

To sum up we can say that the proportion of green algae has increased in associations in the coastal waters of the Hogland Island. *Cladophora glomerata* often serves as a dominant even at a depth of 5 m. *Cladophora glomerata* and *Enteromorpha intestinalis* were found to flourish in the inner part of Suurkylä Bay. The significance of *Cladophora rupestris* has also increased in comparison with its position in 1940.

SUMMARY

The macrophytobenthos characterizes the state of the marine bottom during extended periods. It can be considered to depict the influence of a complex of ecological conditions during such a period.

It would be necessary to differentiate between the effect of eutrophication on the bottom vegetation and the effect of pollution with toxic substances, although this is very often not easy. In any case, pollution with toxic substances mainly takes place in the Gulf of Finland. The inner parts of Tallinn, Kopli, Muuga, Ihasalu, Narva, Luuga, Koporye and Neva Bays have areas completely lacking vegetation, which is most likely due to the immediate harmful effect of industrial waste water. In addition, remarkable changes have taken place in the floristic composition and biomass, as well as in the morphological properties of the algal thallus.

Weak and moderate eutrophication favours the growth and development of the bottom vegetation, while strong eutrophication usually has a negative influence and can cause general disappearance of the vegetation. In connection with increasing eutrophication, changes in floristic composition take place, the mutual quantitative relationships between the species in communities become evident, the role of some species decreases and they may finally completely disappear, and are replaced by other species.

Since the structure of plant communities in the Baltic Sea is very simple, the general rule concerning the simplification of their structure as a result of pollution is not valid here. On the contrary, their structure becomes even more complicated on account of the mass development of epiphytes. In case of weak and moderate eutrophication the biomass of communities can increase or decrease depending on the dimensions of the species dominating in such conditions. Strong eutrophication causes a decline in plant communities until they finally perish.

In conclusion a scheme depicting the changes that have taken place in the most extensively distributed associations during the last two decades is presented.

On hard bottoms:

The ass. *Fucus vesiculosus*	the *Cladophora glomerata* variant of the ass. *F. vesiculosus* the ass. *Cl. glomerata* the ass. *Enteromorpha intestinalis* the epiphyte-rich variant of the ass. *F. vesiculosus* areas without vegetation
The epiphyte-rich variant of the ass. *F. vesiculosus* with *Elachista fucicola*, *Pilayella littoralis*, *Ectocarpus confervoides*	the epiphyte-rich variant of the ass. *F. vesiculosus* without *Elachista* areas without vegetation

On sediment bottoms:

The ass. *Chara aspera*	the *Cladophora glomerata* variant of the ass. *Ch. aspera* the ass. of the loose-lying dwarf forms of *F. vesiculosus* areas without vegetation
The *Cladophora glomerata*-*Rhizoclonium riparium* variant of the ass. *Chara aspera*	the *Cl. glomerata* variant of the ass. *Ch. aspera* areas without vegetation

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MACROPHYTE VEGETATION AND TROPHIC STATUS OF THE GULF OF FINLAND - A REVIEW OF FINNISH INVESTIGATIONS

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1. INTRODUCTION

The northern shore of the Gulf of Finland has a geomorphologically diverse structure on a small scale. The Precambrian bedrock, which consists mainly of resistant granite and gneiss, is an ancient peneplain, now slightly tilted towards the south (Hausen 1931:19-20). The present surface of the peneplain was given a smoothly irregular topography by the last glaciation, a topography which has been only slightly modified by postglacial sedimentation and by wave-action during land uplift. Thus an extensive archipelago was formed along the south coast of Finland. Due to the tilt of the peneplain, the islands are largest near the coast, gradually decreasing in size and total area towards the south. Sediment bottoms are dominant near the coast where they form most of the shoreline, while towards the south they descend to greater depths. Moreover, several rivers discharge along the coast (Fig. 1).

Thus several different gradients have been formed, on moving from the coastline towards the open Gulf of Finland, which greatly influence the occurrence of macrophytes in the area. Among them can be recognized water depth, substrate, wave

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exposure, salinity, temperature, nutrient concentrations, etc. Häyrén (1900, 1903) was the first to integrate some of these factors into a classification of archipelago zones. Subsequently he developed his classification further to take into account much of the aquatic and terrestrial biota (Häyrén 1903, 1913, 1914, 1931b, 1940b). With slight amendments by Luther (1951a, 1961a) for the Tvärminne area, Häyrén's archipelago zonation is still frequently referred to and applied to other archipelagoes (Fig. 2). In addition, it should be recognized that there are gradients in the east-west direction along the coast. Perhaps the most prominent of these is the gradient of decreasing salinity towards the east.

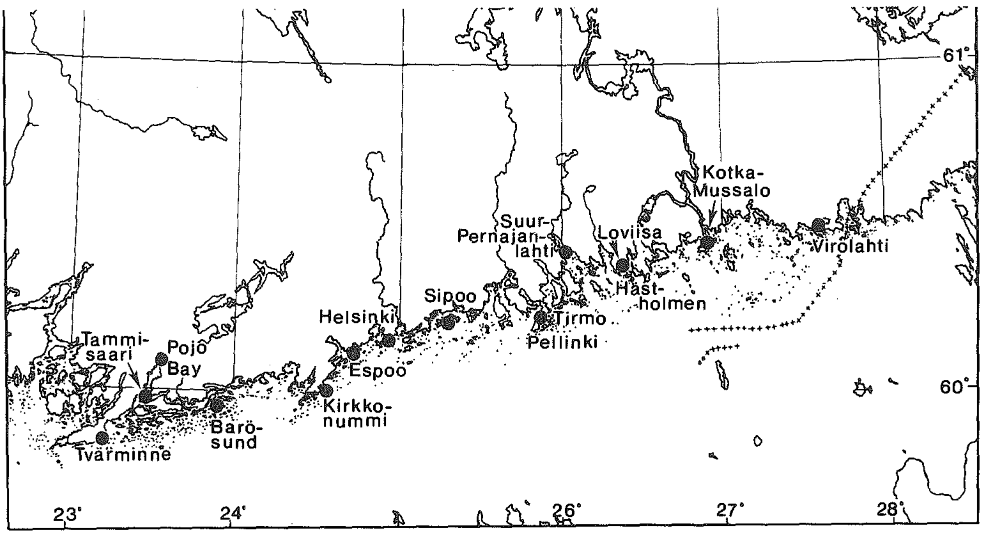

Fig. 1. Investigation areas.

Häyrén was also the first to study the effect of land uplift on the succession of vegetation on sedimentary shores in the Gulf of Finland. Nowadays, since land uplift in the area proceeds at a rate of ca. 0.3 - 0.4 m per century, the process has a slow but definite influence on all littoral biotopes (cf. also Hällfors 1984).

Aquatic macrophytes, that is, aquatic vascular plants and mosses, and macroscopic algae, form phytobenthic communities on suitable substrates in the littoral and sublittoral belts. The most favoured substrates for rhizophytes (most vascular plants and the charophytes) are stable sediments in the coastal zone and the inner archipelago zone, and in sheltered localities in the outer archipelago zone. The outer archipelago zone and the sea zone are dominated by rocky shores and bottoms. Haptophytic algae are dominant on these hard substrata. Where sediment bottoms are found in the littoral or sublittoral at exposed localities, they mainly consist of mobile and thus rather barren sand or gravel. Loose-lying (benthopleustophytic) communities are mainly found on sublittoral soft bottoms. Thus the macrophyte vegetation distinctly changes across the archipelago zones. In addition, there is a very gradual change along the coast which is mainly caused by a salinity gradient.

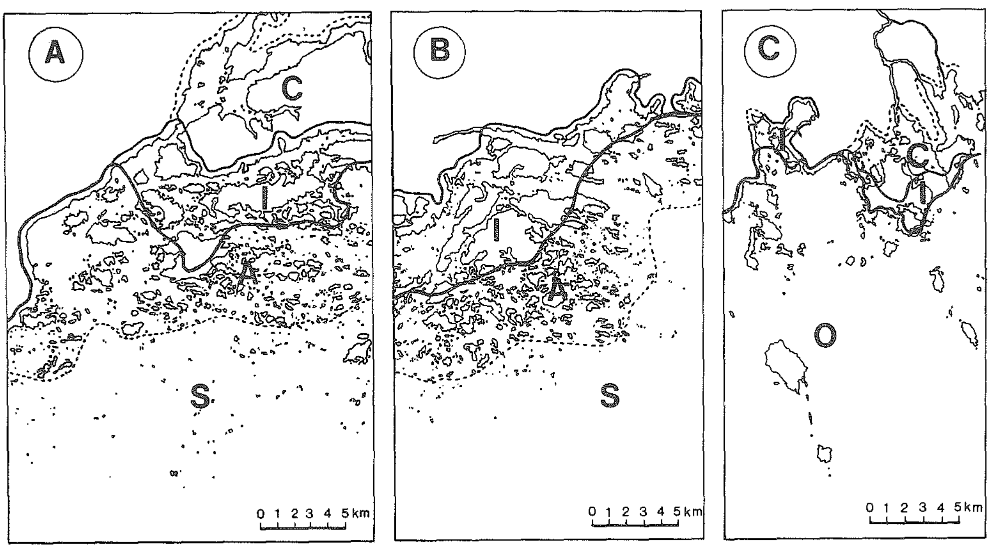

Fig. 2. Archipelago zones in different parts of the northern coast of the Gulf of Finland. A. Tvärminne-Pojo Bay area. B. Barösund area. C. Kotka-Mussalo area. S = sea zone, O = outer archipelago zone. I = inner archipelago zone. C = coastal zone (modified after Ulvinen 1937).

As a result of man's activities several areas along the Finnish coast of the Gulf of Finland are receiving a load of inorganic nutrients and organic pollutants. The majority of the most severely affected areas are located near the mouths of rivers. This gives rise to problems when using bioindicators to assess the degree of eutrophication, because the salinity gradient is inversely related to the nutrient gradients. In this case, basic research in areas with minimum pollution impact has proven to give valuable background data (e.g. Luther 1951a, b, Luther et al. 1975, Hällfors et al. 1975, Lappalainen et al. 1977, Kangas et al. 1982).

One of the greatest difficulties in assessing the state of eutrophication in the archipelago has been that water masses of different trophic status tend to move as packages in an as yet unpredictable way. Infrequent sampling of the water phase, whether concerning physical or chemical parameters, or the plankton community, may give quite variable results depending on what kind of water mass happened to be sampled. Frequent sampling during a prolonged period of time is required if the dynamics of a locality are to be fully understood. Such investigations are still too few, and have thus far been performed only in the Tvärminne area (Niemi 1975, Hällfors et al. 1983).

Attached communities of organisms are potentially useful as bioindicators because they are thought to integrate, in their composition, the effects of the consecutive water masses affecting the biotopes. Different time scales are involved with regard to different types of organisms. Periphyton communities are highly dynamic, and react rapidly to environmental changes, that is, within days or a couple of weeks, at most. Macrophyte communities react more slowly, ephemeral filamentous algae usually within one to several weeks, annuals from one year to another, and perennials over a succession of years.

The phytobenthos, particularly the rich *Fucus vesiculosus* community along the Baltic shores, is an important nursery ground for many fish species of economical value. Thus deleterious changes in this community may cause damage to the Baltic ecosystem. Since the status of Baltic coastal waters has to be reported to the Helsinki Commission, the interest in phytobenthic research is expected to increase.

Trei et al. (1987) have reviewed the macrophyte studies carried out along the Soviet coast of the Gulf of Finland and the neighbouring sea areas, and evaluated the associations and species as indicators of coastal water of different trophic status. The aim of the present paper is to review the literature on macrophyte studies performed along the Finnish coast of the Gulf of Finland, to sum up the results on macrophytic studies in undisturbed and polluted areas, and to evaluate different methods for using changes in aquatic vegetation as indicators of the trophic status of coastal waters.

Microphytes will not be considered, except in cases where they were originally treated as an integral part of the phytobenthic community. This especially concerns the saprobic system of Häyrén (p. 122 et sec). Thus several microphytes have been included in Table 3.

The geographical area covered in this review (Fig. 1) extends from the tip of the Hanko peninsula in the west (23°E, cf. Hällfors 1979) to the Finnish-Soviet border in the east. Owing to this geographical limitation, several significant papers on macrophytes in the Archipelago Sea and the Åland Islands, where the environmental conditions are closely reminiscent of those in the Gulf of Finland, could not be given the attention they deserve (e.g. Ravanko 1968, 1972, Peussa & Ravanko 1975, Rönnberg 1981, Rönnberg et al. 1985, Haahtela & Lehto 1982, Haahtela 1984). Furthermore, the monograph of Wærn (1952) concerning the algal flora and vegetation of the Swedish side of the Åland Sea, and the papers of Wallentinus (1976, 1979) on the algae and aquatic phanerogams in the Askö area south of Stockholm, contain much useful information.

2. REVIEW OF INVESTIGATIONS

a) Regional basic research in undisturbed areas

Pioneering work on macrophytes at the northern coast of the Gulf of Finland was done by Gobi in the 1870s (Gobi 1874, 1877a, b, Gobi & Grigoriew 1873). Häyrén published a number of papers on the subject between 1900 and 1958. The regional distribution of aquatic plants was presented in his studies on the archipelago zones (Häyrén 1900, 1931b). In his works on the littoral and sublittoral vegetation in the archipelago of western Nylandia (Häyrén 1902, 1910b), background information was given about different species and associations. Ulvinen (1937) studied the aquatic plants in the archipelago off the Kymi river estuary in eastern Nylandia, and Häyrén (1949) described the aquatic vegetation in the Suur-Pernajanlahti (Stor-Pernåviken) bay east of Loviisa. Especially Häyrén, but also other botanists, have published a number of short papers on the flora and vegetation in different archipelago areas (included in the bibliography).

A milestone in brackish-water macrophyte investigations was Luther's (1951a, b) comprehensive work on the distribution and ecology of water plants in the Pojo Bay and the Tammisaari-Tvärminne archipelago. This work has received considerable international recognition among brackish-water researchers (e.g. Remane and Schlieper 1957). Luther's detailed studies on the autecology of macrophytic species has provided a sound basis for further studies on their indicative value when assessing the trophic status of a water body in the coastal areas of the Baltic Sea. His papers mirror a deep understanding of taxonomical and ecological aspects, objects too much neglected in research today (see also Luther 1947a, b, c, d, 1949, 1950a, b, c, 1953a, b, c). His work on the flora and vegetation in the Pojo Bay and in fladas of different developmental stages in the archipelago outside Tammisaari (Ekenäs) and Tvärminne have been continued by Munsterhjelm (1985a, b).

Several works on the flora and vegetation of different archipelago areas have been published as reports or have been deposited as mimeographed M.Sc. theses in the library of the Department of Botany at the University of Helsinki (included in the bibliography).

b) Studies in polluted coastal waters

Ernst Häyrén (1910a, 1921, 1922, 1933, 1937, 1944, 1945c) studied the macrophyte and algal associations in several coastal areas in order to find out the influence of pollution on the littoral and sublittoral vegetation. On the basis of these studies, Riska (1970), Ray (1974) made a reinventory of the aquatic vegetation off Helsinki. The changes in the vegetation showed that the polluted area around Helsinki had increased. Lindgren (1975, 1978) was the first to study the algal vegetation in the archipelago area off Helsinki, Espoo and Kirkkonummi by SCUBA diving. He established permanent profiles as a basis for later monitoring of the algal vegetation.

Hällfors and co-workers (Maa ja Vesi 1976, Hällfors et al. 1976) studied the aquatic flora and vegetation in relation to the trophic status of the waters off Helsinki using statistical treatment of the material. The work and development of methods have been continued by Viitasalo (1984, 1985). Munsterhjelm (1983, 1986) has applied these methods with good results in his studies in the Pojo Bay - Tvärminne archipelago area.

Studies on the influence of pollution on the aquatic and littoral vegetation have also been performed in other areas. The results have been presented in mimeographed reports or as M.Sc.

theses. Holmberg (1981, 1986) described the aquatic plants in waters off Hanko affected by pollution. Kuuppo (1957), Kaasinen (1974) and Hosiaisluoma (1980, 1981) studied the inner bays in the surroundings of Helsinki. Toivonen et al. (1982) described the aquatic vegetation in the Porvoo-Tirmo archipelago as a basis for monitoring in an area where the building of embankments and bridges will essentially change the water circulation pattern in the future.

Ilus et al. (1980, 1987) have studied the changes in the aquatic vegetation caused by thermal pollution from the nuclear power plant off Loviisa.

The major investigations mentioned in the previous chapters are summarized in Table 1. Short comments are made as to their localities, methodology and possible relationship to water pollution. Minor reports and short communications are not included. As is readily evident from the table, there has been a clear shift in the emphasis of the studies from floristic and phytogeographical aspects to ecology and environmental science. Nevertheless, many of the older studies deserve a place as excellent baseline sources for later research work. Today, many of them exist only as single specimens in the archives of the Finnish botanical libraries. Reproduction of them in one form or another would be warmly welcomed.

Table 1. Regional phytobenthos studies and their relation to pollution.

Reference	Study area	Type of study	Comments in relation to discharges
Brenner 1921	Barösund archipelago	phytogeographic	Baseline, still clean inner archip.
Häyrén 1921	Helsinki Peninsula	saprobic system	Starting point of pollution assessment
Harjama 1935	Helsinki, Degerö	floristic mapping, M.Sc.thesis	Later studies 1970-80
Ulvinen 1937	Kymi river estuary	phytogeographic	Pulp and paper mills since the study
Luther 1951a, b	Pojo Bay-Tvärminne	phytogeographic	Baseline study
Kuuppo 1957	Helsinki, Laajalahti	floristic mapping, M.Sc.thesis	Later studies 1970-80
Lappalainen 1963	East of Kotka	phytogeographic, MSc.thesis	
Haikonen 1967	Tvärminne	M.Sc.thesis	
Kulomäki 1971	Virolahti	phytogeographic, M.Sc.thesis	
Ray 1974	Helsinki, harbours	saprobic system, M.Sc.thesis	Parallels to Häyrén, Enteromorpha-taxonomy
Kouri 1974	Virolahti	ecological, M.Sc.thesis	
Kaasinen 1974	Helsinki, Vanhan-kaupunginlahti	ecological, M.Sc.thesis	Municipal discharges, low salinity
Maa ja Vesi 1976	Helsinki sea area	saprobic and numerical system	
Lindgren 1978	Sipoo-Helsinki-Kirkkonummi	16 permanent lines, SCUBA-diving	Baseline study
Holmberg 1981	Hanko Peninsula	34 profiles, skin-diving, M.Sc.thesis	Parallels to Häyrén 1944
Laurola 1982	Tvärminne	seasonal cycles, skin-diving, M.Sc.thesis	Baseline study
Munsterhjelm 1983	Tammisaari-Tvärminne	saprobic system	
Toivonen et al. 1982	Tirmo-Pellinki	phytogeographic	Embankment impacts
Viitasalo 1984	Helsinki, Espoo	saprobic and numerical system	
Heinonen 1986	Hanko Peninsula	M.Sc.thesis	
Ilus, Keskitalo 1986	Loviisa, Hästholmen	10 profiles, SCUBA-diving	Thermal discharges

c) Studies on macrophyte biomass, production and metabolism

Relatively little is known about the quantitative distribution of macrophytes in the area, and even less about their productivity. The earliest biomass estimates concerned *Fucus vesiculosus* in Pellinki (Pellinge) and Tvärminne (Segerstråle 1928, 1944), and are hardly more than semiquantitative, serving as background data for the estimation of the abundance and biomass of the fauna associated with *Fucus* stands.

During the IBP-PM project in 1968-72 a wealth of quantitative data was collected during different seasons from a number of different undisturbed biotopes, mainly in the outer archipelago zone and the sea zone at Tvärminne (Luther et al. 1975). Only a part of the material has so far been published (Hällfors et al. 1975, Lappalainen et al. 1977, Kangas & Hällfors 1978, Kangas et al. 1982).

Further quantitative data are provided by Lindgren (1978) for the area near Helsinki, where both relatively undisturbed localities and localities to a varying degree influenced by municipal effluents were sampled. Ilus & Keskitalo (1980, 1987) contributed with data for the area influenced by thermal effluents from the Loviisa nuclear power plant.

Only three publications deal with productivity aspects of macrophytes. Elmgren & Ganning (1974) provided results from two localities at Tvärminne, based on diel oxygen curves in enclosures. Verhoeven (1980b) and van Vierssen (1982b) gave productivity estimates for *Ruppia* and *Zannichellia* spp., respectively, on the basis of biomass changes in several stands in the Tvärminne area. It is evident that many more productivity measurements are needed before a clear picture of the spatial and temporal aspects of macrophyte production is obtained. Progress is slow, mainly because of methodological difficulties and lack of funding.

b) Other studies on macrophytes

Häyrén (1931a) and Luther (1947a) studied the systematics and ecology of the genera *Zannichellia* and *Ruppia*, and Cedercreutz (1937, 1938) and Ulvinen (1955) the charophytes.

Several papers have been published on the occurrence and ecology of macroalgae (including filamentous species) by Häyrén (1911, 1912, 1940a, b, 1947, 1955), Boström (1936, 1937), South (1965), Norton and South (1969), Wallentinus (1974), Lindgren (1975) and Hällfors et al. (1984). A lot of studies have been made on the occurrence and ecology of the bladder-wrack *Fucus vesiculosus* (Strandström 1980, Luther 1981a, Kangas et al. 1982, Kangas 1983, Hällfors et al. 1984, Kangas & Niemi 1985) and, as earlier mentioned, on its decline in the outer archipelago areas during the seventies and eighties.

The seasonal dynamics of filamentous algae on hard bottoms in the hydrolittoral belt was studied by Laurola (1982) in the archipelago at Tvärminne. This subject has been followed too little. There is very little information about the environmental and biotic factors regulating the seasonal dynamics of the hydrolittoral primary producers. Luther and Munsterhjelm (1983) investigated the influence of the termination of cattle grazing on the hydrolittoral vegetation on soft bottoms.

Luther (1983) published a thorough review of the life forms, and above-ground and below-ground biomass of aquatic macrophytes. He discusses in detail the problems arising in the quantitative estimation of the biomass of water plants and helophytes.

Van Vierssen (1982a, b) investigated the community ecology of *Zannichellia*-dominated aquatic vegetation, and Verhoeven (1979, 1980a, b) the same of *Ruppia*-dominated vegetation in the archipelago at Tvärminne.

The first ecophysiological approaches to the adaptation of macrophytes to low salinities in the Baltic Sea have been made by Russel (1985a, b, 1986).

3. METHODOLOGICAL ASPECTS OF MACROPHYTE FLORA AND VEGETATION AS INDICATORS OF THE TROPHIC STATUS OF COASTAL WATERS

a) The saprobic system of Häyrén

Quite early on Häyrén seems to have become interested in problems related to pollution in the coastal waters of the Gulf of Finland. His first article on the topic (Häyrén 1910a), on the saprobic affinity of some *Enteromorpha* species, was clearly inspired by the pioneering work of Kolkwitz & Marsson (1908). Extensive field studies in 1919-20 resulted in his main work on the effects of pollution on the littoral vegetation and flora in the harbour area of Helsinki (Häyrén 1921), with two short summaries (Häyrén 1922, 1923a, b). In these he laid the foundation for his saprobic system which was mainly based on Kolkwitz & Marsson (1908). However, it had to be considerably modified for brackish-water conditions, marine *Enteromorpha* species forming an essential part of Häyrén's classification. The first study was followed up in 1932 (Häyrén 1933a, 1936b, c) and 1936 (Häyrén 1937), in order to examine the effects of improved sewage treatment. Later, Häyrén (1944) widened the scope of his saprobic investigations to include five more coastal towns, viz. Hanko, Tammisaari, Porvoo, Loviisa and Viipuri (the last-mentioned now being U.S.S.R. territory). The material for this study was mostly collected during occasional excursions in 1920-40. The same material was used for a floristic article (Häyrén 1945b). Investigations in 1946 on the unpolluted bay Suur-Pernajanlahti resulted in the last work of a similar scope (Häyrén 1949).

The saprobic studies of Häyrén (1921-49) were all published in Swedish, some with short German summaries (Häyrén 1921, 1933, 1937, 1944 and 1949), except for one short account in Finnish (Häyrén 1923a). This is probably why his investigations have not received the international attention they might deserve. Outside Finland only Wallentinus (1979) has used his results to some extent. We thus consider it necessary to review his results in some detail.

Häyrén published no detailed account of his field methods. From his published results, however, supplemented by a few surviving anecdotes, it appears that he made most of his collections and field notes while walking along the shore, occasionally wading to make observations to a maximum depth of ca. one metre. Only in his publication on the Suur-Pernajanlahti (Häyrén 1949) is it evident that he must have used a boat. He made notes on the visually recognizable dominant vegetation elements, which formed the basis for his "associations". Samples were collected and later microscopically analysed, mainly for microphytes, in the laboratory. With his accumulated experience of the familiar saprobic associations he was capable of rapid surveys of long stretches of shoreline (Häyrén 1933, 1937). However, except for his second work on Helsinki (Häyrén 1933), he did not rely merely on the associations, but listed species and their abundances in the descriptions of the localities. With his wide taxonomical knowledge he recorded not only aquatic macrophytes, but also bacteria, microalgae and phycomycetes as well as geolittoral lichens, fungi, mosses and vascular plants.

Table 2 (p. 124) lists the benthic associations of Häyrén as he classified them according to saproby and salinity. For the sake of completeness some important benthic microphytic associations have been included.

For practical shore-bound work Häyrén (1921:55-56) considered the monitoring of only five hard-bottom associations to be necessary, viz. 1) Polysaprobic *Bacterietum compactum*, smelly greyish gruel, of white coating of tufts; 2) strongly mesosaprobic *Enteromorphetum pallidum*, green *Enteromorpha* with

Table 2. The brackish-water associations recognized by Häyrén (1921, 1933, 1937, 1944, 1949), listed according to saprobic affinity as originally determined by Häyrén. The dominant and main associated species are indicated. Planktonic and some microphytic associations have been excluded.

<u>Polysaprobic association</u>	
Bacterietum compactum (Häyrén 1921, 1933, 1937, 1944)	Small bacteria, filamentous spp. (Beggiatoa spp., Sphaerotilus natans)
<u>Strongly mesosaprobic associations</u> (α-mesosaprobic)	
Bacterietum rosaceum (Häyrén 1944)	Pink or grayish cover of mainly sulphur bacteria on mud or decaying macroalgae
Oscillatorietum benthonicum (Häyrén 1921, 1933, 1937, 1944)	Oscillatoria amphibia, O. chalybaea, O. formosa, O. neglecta, O. okenii, O. tenuis, Spirulina subsalsa, Phormidium autumnale, Lyngbya aestuarii, etc.
Enteromorphetum albidum (Häyrén 1921, 1933, 1937, 1944)	Enteromorpha ahlneriana, Thiothrix nivea, Sphaerotilus natans (+ Phragmidiothrix multiseptata)
Ulothricetum albidum (Häyrén 1921)	Ulothrix subflaccida, Sphaerotilus natans, Thiothrix nivea, Oscillatoria agardhii, Phormidium autumnale
Cladophoretum albidum (Häyrén 1921, 1933, 1944)	Cladophora glomerata, Thiothrix nivea, Sphaerotilus natans
Potamogetonetum (P. perfoliatus) saprobicum (Häyrén 1921)	Potamogeton perfoliatus, Sphaerotilus natans, Thiothrix nivea, Lamprocystis roseopersicina
Phragmitetum saprobicum (Häyrén 1921)	Phragmites australis, bacteria, Euglena viridis, Enteromorpha ahlneriana
<u>Weakly mesosaprobic associations</u> (β-mesosaprobic)	
Enteromorphetum fluitans (Häyrén 1921, 1933, 1937, 1944)	Loose-lying Enteromorpha flexuosa, E. ahlneriana (+ E ?compressa, Mougeotia, Spirogyra, Ulothrix, Pilayella littoralis, Cladophora glomerata, etc.)

Ulothricetum improvisum (Häyrén 1921, 1933, 1937, 1944)	Ulothrix subflaccida, Enteromorpha ahlneriana, diatoms (+ Capsosiphon fulvescens, Urospora penicilliformis)
Ulothricetum mixtum (Häyrén 1921)	Ulothrix subflaccida, U. pseudoflacca, (+ Enteromorpha ahlneriana)
Ileetum fulvo-viride (Häyrén 1921, 1933, 1944)	Capsosiphon fulvescens, Ulothrix subflaccida, Enteromorpha ahlneriana (+ diatoms, Phormidium spp.)
Phormidietum membranaceum (Häyrén 1921, 1933, 1937, 1944)	Phormidium autumnale, P. corium, P. tenue (+ Calothrix scopulorum, Sphaerotilus natans, Stigeoclonium tenue, etc.)
Enteromorphetum obscure-viride (Häyrén 1921, 1933, 1937, 1944)	Enteromorpha ahlneriana, E. flexuosa (+ Cladophora glomerata, Ectocarpus siliculosus, Enteromorpha intestinalis)
Cladophoretum dilute-fuscum (Häyrén 1921, 1933, 1937, 1944)	Cladophora glomerata, abundant diatoms (+ Ulothrix, Sphaerotilus)

Acc. to Häyrén (1933) weakly mesosaprobic only when occurring close to the surface, oligotrophic and katharobic at greater depth

Vaucherietum arenicolum (Häyrén 1921, 1933, 1937, 1944)	Vaucheria sp. (+ Enteromorpha ahlneriana, Lyngbya aestuarii, Spirogyra)
Percursarietum arenicolum (Häyrén 1921)	Percursaria percursa (+ Enteromorpha ahlneriana)

<u>Oligosaprobic associations</u>

Algetum congestum (Häyrén 1921, 1933, 1944)	Loose-lying Cladophora glomerata, Ectocarpus siliculosus, Melosira spp., Spirogyra, Lyngbya aestuarii, Rhizoclonium riparium, etc. (Häyrén 1921). Also (Häyrén 1944) Chara aspera, Dictyosiphon foeniculaceus, Fucus vesiculosus, Pilayella littoralis, Stictyosiphon tortilis, Lyngbya majuscula, Tolypothrix tenuis

Lemnetum submersum (Häyrén 1921, 1949)	Lemna trisulca very abundant (+ Lamprocystis roseopersicina, Oscillatoria tenuis, Lyngbya aestuarii, Potamogeton perfoliatus, Sparganium minimum, Myriophyllum spicatum, Najas marina, Zannichellia, etc.)
Cladophoretum fluitans (Häyrén 1921, 1933, 1944)	Loose-lying Cladophora glomerata (+ Enteromorpha flexuosa, E. ?compressa, Spirogyra, Lyngbya aestuarii, Anabaena, diatoms, Percursaria percursa, Rhizoclonium riparium)
Aegagropiletum benthonicum (Häyrén 1944, 1949) Also katharobic	Cladophora aegagropila, attached or forming balls (+ Rhizoclonium riparium, Cladophora fracta, Chaetomorpha, Spirogyra, Drepanocladus, Chara tomentosa, Myriophyllum spicatum, Potamogeton perfoliatus)
Vaucherietum fluitans (Häyrén 1921)	Loose-lying Vaucheria sp. (+ Bacillaria paxillifer, Oscillatoria tenuis)
Vaucherietum profundum (Häyrén 1944, 1949) Also katharobic	Vaucheria sp. (+ Potamogeton perfoliatus, P. pectinatus, Rhizoclonium riparium, Lyngbya aestuarii, L. majuscula, Cladophora aegagropila, etc.)
Spirogyretum oligosaprobicum (Häyrén 1944)	Attached sterile Spirogyra (+ Cladophora glomerata, Enteromorpha ahlneriana, E. flexuosa, Mougeotia, Oedogonium)
Zygnemaletum infusum (Häyrén 1944, 1949)	Loose-lying flocs inside the helophyte belt, of Mougeotia, Spirogyra, and/or Zygnema (+ Oedogonium, Vaucheria, etc.)
Diatometum fuscum (Häyrén 1921, 1933, 1937, 1944)	A few mm thick carpet of diatoms, especially Gomphonema olivaceum and Rhoicosphenia abbreviata (+ Diatoma elongatum, D. vulgare, Synedra tabulata, etc.)
Enteromophetum pallide-viride (Häyrén 1921, 1933, 1937)	Entromorpha flexuosa, E. ahlneriana, E. intestinalis, Cladophora glomerata, Pilayella littoralis

Ceratophylletum oligosaprobicum (Häyrén 1944)	Ceratophyllum demersum (+ Najas marina)
Potamogetonetum (P. filiformis) saprobicum (Häyrén 1921)	Potamogeton filiformis, diatoms, Ectocarpus siliculosus (+ Ceramium tenuicorne, Enteromorpha ahlneriana, Stigeoclonium tenue)
<u>Katharobic associations</u>	
Calothricetum lubricum (Häyrén 1921, 1933, 1937, 1944, 1949)	Calothrix scopulorum (+ Rivularia atra, R. biasolettiana, Ulothrix subflaccida, Phormidium autumnale, P. corium, Enteromorpha ahlneriana, E. flexuosa)
Rhizoclonietum fluitans (Häyrén 1949)	Floating Rhizoclonium riparium (+ Cladophora fracta, Oedogonium, Lemna trisulca)
"Possibly a variant of the oligosaprobic Cladophoretum fluitans"	
Cladophoretum salinum (Häyrén 1921, 1933, 1937, 1944, 1949)	Cladophora glomerata (+ Pilayella littoralis, diatoms, Enteromorpha flexuosa, E. ahlneriana, E. intestinalis, Ceramium tenuicorne, Ectocarpus siliculosus, etc.)
Fucetum balticum (Häyrén 1921, 1944, 1949)	Attached Fucus vesiculosus (+ epiphytic Ceramium tenuicorne, Ectocarpus siliculosus, Pilayella littoralis, Cladophora glomerata, Elachista fucicola, etc.)
Fucetum benthonicum (Häyrén 1949)	Loose-lying Fucus vesiculosus (+ Potamogeton perfoliatus, P. pectinatus, Ceratophyllum demersum, Myriophyllum spicatum)
Potamogetonetum (P. perfoliatus) purum (Häyrén 1921, 1949)	Potamogeton perfoliatus (+ entangled Cladophora glomerata, Ectocarpus siliculosus, Spirogyra, Lyngbya aestuarii, and P. pusillus (= panormitanus), Zannichellia palustris, etc.)

Charetum arenicolum (Häyrén 1921, 1944, 1949)	Chara aspera (+ Eleocharis acicularis, Potamogeton filiformis and entangled filamentous algae, Ectocarpus siliculosus, Cladophora glomerata, Rhizoclonium riparium, etc.)
Charetum rufum (Häyrén 1949)	Chara tomentosa (+ Potamogeton pectinatus, P. perfoliatus, Myriophyllum spicatum, Chara aspera, Najas marina, etc.)
Myriophylletum purum (Häyrén 1944, 1949)	Myriophyllum spicatum (+ Najas marina, Zannichellia, diatoms, Oedogonium, Zygnematales, Lemna trisulca, Potamogeton pectinatus, P. perfoliatus, etc.)
Zannichelletum benthonicum (Häyrén 1949)	Zannichellia palustris, Z. pedunculata (+ Eleocharis acicularis, Myriophyllum spicatum, Najas marina, Potamogeton pusillus (= panormitanus)
Phragmitetum purum (Häyrén 1921, 1944, 1949)	Phragmites australis
Grandiscirpeta (Häyrén 1921, 1944, 1949)	Bolboschoenus maritimus, Schoenoplectus tabernaemontani
Typhetum purum (Häyren 1944, 1949)	Typha angustifolia
Rivularietum litoreum (Häyrén 1944, 1949)	Rivularia nitida, R. biasolettiana (= R. atra ?)
Najas marina association (Häyrén 1949)	Najas marina (+ Myriophyllum spicatum, Potamogeton pusillus (= panormitanus), Drepanocladus)
Callitriche autumnalis association (Häyrén 1949)	Callitriche hermaphroditica (+ Eleocharis acicularis, Littorella uniflora, Zannichellia palustris, Drepanocladus, filamentous algae)
Batrachium circinatum association (Häyrén 1949)	Ranunculus circinatus (+ Myriophyllum spicatum)

Ruppia rostellata association (Häyrén 1949)	Ruppia maritima (+ Zannichellia palustris)
Potamogeton pectinatus association (Häyrén 1949)	Potamogeton pectinatus (+ Lemna trisulca, Ceratophyllum demersum, Myriophyllum spicatum, Potamogeton perfoliatus, etc.)
Scirpus acicularis association (Häyrén 1949)	Eleocharis acicularis (+ Chara aspera, Hippuris vulgaris, Potamogeton pusillus (= panormitanus), Zannichellia, Drepanocladus, etc.)

white coating of bacteria; 3) weakly mesosaprobic *Enteromorphetum obscure-viride*, dark green 1 to 5-dm-long algal tufts; 4) very weakly mesosaprobic *Ulothricetum improvisum*, bright green 1 to 3-cm-long fine fluff (not as important as the other associations); 5) oligosaprobic *Enteromorphetum pallide-viride*, light green, 0.5 to 2-dm-long tufts, in deeper water.

Where these associations were lacking the water would be undisturbed and practically clean. In addition, Häyrén emphasized that the evaluations should be made at the height of the growing period in July-September, during calm weather, and not before a few days had passed after strong winds because the white (bacterial) coatings were easily removed by wave action, which might give misleading results.

A considerable amount of time elapsed after the works of Häyrén without any attempts to develop his ideas. Ray (1974) adopted his classification only in the late 1960s. One important aspect of Ray's work was that she apparently was fairly successful in interpreting Häyrén's *Enteromorpha* nomenclature in the modern terms of Bliding (1963). Her results showed that the polluted areas had increased considerably due to the increased volume of sewage, but that the strongly polluted localities had not increased in the same proportion because of more efficient purification.

Ray divided the aquatic macrophyte associations into the same five saprobic classes as Häyrén:

- polysaprobic (in the most polluted areas)
- alpha-mesosaprobic
- beta-mesosaprobic
- oligosaprobic
- katharobic (undisturbed in relation to pollution)

The strongly and moderately polluted areas continued to decrease during the 1970's, while the weakly polluted and eutrophicated areas slightly expanded (Maa ja Vesi 1976, Hällfors et al. 1976, Viitasalo 1984, 1985). In these investigations the still somewhat subjective associations of Häyrén were no longer strictly adhered to, but instead a numerical index of saproby was used that was calibrated with the earlier results of Häyrén and Ray (Section 3. b).

The main interest of Häyrén and of Ray lay with the most saprobic associations. Later, when sewage control measures had advanced, the need for more detailed classification of the less disturbed areas led to different additions to the main classes:

Maa ja Vesi (1976) added a "eutrophic" zone between the oligosaprobic and katharobic zones of Häyrén and of Ray, based on the concept that the organic matter in this zone was fully mineralized but that the nutrient concentrations were still higher than in undisturbed (katharobic) waters.

Kolkwitz & Marsson (1902) considered as katharobic only those plants which grow in extremely electrolyte-poor waters; fountains, melting water etc. Häyrén considered all "natural" associations as katharobic. Later on some of them were found to thrive well in areas subjected to a slight sewage effect. Caspers & Karbe (1966) called such areas and organisms beta-oligosaprobic. The latter division was adopted also by Viitasalo (1984) who divided the oligosaprobic class into alpha- and beta-oligosaprobic classes.

Viitasalo (1985) has tried to make a comparison between the different terminologies described above. It is reproduced with slight modifications and comments in Fig. 3.

b) Numerical approaches to saprobic classification

It is a practice to consider that vegetation exists as communities or associations which are determined by ecological and competitive factors. It is a common experience that the

Elster (1958), ym	hypertr.	"rasante"e.	eutrophic		oligotrophic	
Kolkwitz & Marsson (1902)	polysapr.	mesosaprobic		oligosaprobic		katharobic
Häyrén (1921), Ray (1974)	polysapr.	mesosaprobic		oligosaprobic	katharobic	
Maa ja Vesi (1979)	polysapr.	α mesos.	β mesos.	oligosaprobic	eutrophic	katharobic
Caspers & Karbe (1966)	polysapr.	α mesos.	β mesos.	α oligosapr.	β oligosapr.	katharobic
Viitasalo (1985)	polysapr. (heavily) polluted)	α mesos. (polluted)	β mesos. (slightly polluted)	α oligosapr. (disturbed)	β oligosapr. (slightly d.)	katharobic (undisturbed)
sample saprobic index (S)	+4.0 ... +2.0		+0.1	-1.4	-1.6	-2.0
Qualitative and other criteria		phytopl. Balanus, Cordyloph. Laomedea	Ectoc."fluv." Ceratophyllum, dwarfed Clad. glomer.	E.ahln.,E.prol.<10+%, sterile Fucus Bal+Electra >40% Cladophora cpp, Myriophyllum, Zannichellia cpp	diatoms cpp on Cladophora, Ent.intest.in all surface samples no Elachista no Cl.rupestris Ceramium 10-40%	Cladophora glomerata, Chorda, Dict.chordaria, Najas, Chara Phyllophora

Fig. 3. Comparison between different terminologies for saprobic and eutrophic classification.

structure of classification is strongly dependent on the problem (aspect) to be considered. As an example, vegetation classes with the main emphasis on salinity or on water temperature may be different. Thus a great many classification systems may be constructed even for one and the same phytogeographical area.

In an area with a short growing period, large variation in salinity, temperature and radiation, the growth of slow-growing water plants is retarded or depressed and many of the ecological niches are invaded by annual, fast-growing (opportunistic) species. The degree of stability remains low and the stable co-existence of species is not frequent. Such circumstances are common in the northern parts of the Baltic Sea. The picture becomes even more complicated if such an area of unstable associations is subjected to pollution or some other new stress agent. The stable associations become scattered, and a sliding series of species assemblages is found between them. The continuum pattern of vegetation begins to prevail.

In such circumstances, there is a danger that large amounts of information will remain "between" the recognizable associations, or be suppressed if it is not picked up by certain methods. In the recent surveys on the aquatic (macro)vegetation in the Helsinki and Espoo sea areas an attempt has been made to combine the knowledge of macrophyte associations, indicator species and species abundances (Maa ja Vesi 1976, Hällfors et al. 1976, Viitasalo 1984). Different plant taxa are assigned with integer values according to their relation to municipal sewage. Those values are preliminarily called "taxon specific saprobic values" (s). Examples of "s" values from coastal waters of the Gulf of Finland are listed in Table 3.

The abundances of the different species in a sample or sample plot is taken into account simply by weighing the "s" values by the appropriate abundances (cf. Pantle & Buck 1955 and Marvan et al. 1980:302-303). The final average value which takes into account both the qualitative (saprobic) and quantitative

Table 3. Saprobic classification of aquatic plants in the coastal waters of the Gulf of Finland. With the exception of Häyrén (1921, 1944) the taxon specific indexes (s) have been used for the calculation of sample saprobic indexes (S). Besides macrophytes, a number of characteristic microphytes have been included.

Short characterization of the different saprobic groups, or taxon specific indexes (s):

s	Characterization
4	polysaprobic; favours predominantly anaerobic conditions.
3	α-mesosaprobic; favours or tolerates periodic oxygen depletion.
2	β-mesosaprobic; favours water rich in nutrients and organic matter; tolerates strongly fluctuating oxygen concentrations.
1	oligosaprobic; favours water rich in nutrients and with some organic matter.
0	indifferent in relation to sewage load.
-1	favoured by somewhat elevated nutrient concentrations.
-2	katharobic; prefers areas in the natural state with low nutrient concentrations.

Species	Häyrén 1921, 1944	Maa ja Vesi 1976	Viitasalo 1985
PROCARYOTA			
Anabaena variabilis Kütz. ex Born. & Flah.	-	2	2
Anabaenopsis elenkinii V. Mill.	-	2	-
Aphanizomenon flos-aquae Morren ex Born. & Flah.	2	0	-
Beggiatoa alba (Vauch.) Trev.	4	4	-
Beggiatoa sp(p).	-	4	4
Calothrix scopulorum (Web. & Mohr) C. A. Ag. ex Born. & Flah.	-2	-2	-2
Lyngbya aestuarii Liebm. ex Gom.	1	1	-
Nodularia spumigena Mert. ex Born. & Flah.	2	0	-
Oscillatoria agardhii Gom.	2	2	-
O. chalybea Mert. ex Gom.	3	3	-
O. formosa Bory ex Gom.	3	3	-
O. tenuis C.A. Ag. ex Gom.	3	3	-
Oscillatoria spp.	-	-	3

Species	Häyrén 1921, 1944	Maa ja Vesi 1976	Viitasalo 1985
Phormidium ambiguum Gom.	-	3	-
Ph. autumnale (C.A. Ag.) Gom.	3	3	-
Ph. corium (C.A. Ag.) Gom.	1	1	-
Ph. tenue (Menegh.) Gom.	1	1	-
Phormidium spp.	-	-	1
Rivularia atra Roth ex Born. & Flah.	-2	-2	-2
R. biasolettiana (Menegh.) Born. & Flah.	-2	-2	-
Sphaerotilus natans Kütz. (= Cladothrix dichotoma Cohn)	3	3	-
Tolypothrix tenius Kütz. ex Born. & Flah.	-2	-2	-
RHODOPHYTA			
Callithamnion roseum (Roth) Lyngb.	-	-	-2
Ceramium tenuicorne (Kütz.) Warn (1)	-2	-2	-1
Furcellaria lumbricalis (Huds.) Lamour.	-	-2	-2
Phyllophora truncata (Pall.) Zinova	-	-2	-
Polysiphonia nigrescens (Huds.) Grev.	-2	-2	-2
P. violacea (Roth) Spreng.	-2	-	-2
Rhodomela confervoides (Huds.) Silva	-2	-	-1
FUCOPHYCEAE			
Chorda filum (L.) Stackh.	-2	-2	-2
Dictyosiphon chordaria Aresch.	-	-	-2
D. foeniculaceus (Huds.) Grev.	-2	-1	-1
Ectocarpus siliculosus (Dillw.) Lyngb.	-2	-1	-1
E. siliculosus "fluviatilis-type"	-	-	1
Elachista fucicola (Vell.) Aresch.	-2	-2	-2
Eudesme virescens (Carm.) J.G. Ag.	-	-	-2
Fucus vesiculosus L.	-2	-2	-2
Pilayella littoralis (L.) Kjellm.	-2	-2	-2
Porterinema fluviatile (Porter) Warn	-	-1	-
Sphacelaria arctica Harv.	-	-2	-2
Stictyosiphon tortilis (Rupr.) Reinke	-2	-1	-1

Species	Häyrén 1921, 1944	Maa ja Vesi 1976	Viitasalo 1985
CHLOROPHYTA			
Capsosiphon fulvescens (C.A. Ag.) Setch. & Gardn.	2	2	2
Cladophora aegagropila (L.) Rabenh.	1	-	-
C. fracta (O.F. Müll. ex Vahl) Kütz.	1	1	-
C. glomerata (L.) Kütz. (attached (2))	-2	0	0
(loose (3))	1	0	0
C. rupestris (L.) Kütz.	-	-2	-2
Enteromorpha ahlneriana Bliding (4)	1; 2	2	2
E. clathrata (Roth) Grev.	-	1	1
E. compressa (L.) Grev.	-	1	1
E. flexuosa (Wulf. ex Roth) J.G. Ag. ssp. flexuosa (5)	2	2	2
E. flexuosa ssp. pradoxa (Dillw.) Bliding (6)	1	-	-
E. intestinalis (L.) Link	1	1	1
E. prolifera (O.F. Müll.) J.G. Ag.	-	2	2
Percursaria percursa (C.A. Ag.) Bory	2	2	2
Rhizoclonium riparium (Roth) Harv.	1	1	1
Stigeoclonium tenue (C.A. Ag.) Kütz.	2	3	-
Ulothrix pseudoflacca Wille	1	1	1
U. subflaccida Wille	2	2	2
U. zonata (Weber & Mohr) Kütz	-	-1	-1
Urospora penicilliformis (Roth) Aresch.	1	-1	-1
Chara aspera Wild.	-2	-2	-
Ch. globularis Thuill.	1	-2	-
Ch. tomentosa L.	-	-2	-
Nitellopsis obtusa (Desv.) Groves	1	-	-
Tolypella nidifica (O.F. Müll.) Leonh.	-	-2	-1
MAGNOLIOPHYTA			
Bolboschoenus maritimus (L.) Palla	0	0	0
Ceratophyllum demersum L.	1	1	1
Eleocharis acicularis (L.) Roem. & Schult.	-	0	-
Lemna trisulca L.	1	1	1
Myriophyllum spicatum L. (7)	-2	-1	-1
Najas marina L.	-2	-	-1
Phalaris arundinacea L.	-	0	-

Species	Häyrén 1921, 1944	Maa ja Vesi 1976	Viitasalo 1985
Phragmites australis (Cav.) Trin. ex Steudel	0	0	0
Potamogeton filiformis Pers.	0	-	-
P. pectinatus L.	0	0	0
P. perfoliatus L.	0	0	0
Ranunculus baudotii Godron	-	-2	-2
Schoenoplectus tabermaemontani (Gmel.) Palla	0	0	0
Typha angustifolia L.	-2	-1	-
T. latifolia L.	1	1	1
Zannichellia major Boenn.	-	-2	-
Z. palustris L. (8)	-	-1	-1
Zostera marina L.	-	-2	-

Notes:

(1) Determined by Häyrén as C. diaphanum Harv.
(2) Including Häyrén's determination of C. crystallina (Roth) Kütz.
(3) Determined by Häyrén as C. marina Roth.
(4) Corresponds to the oligosaprobic E. clathrata (Roth) J.G. Ag. and the β-mesosaprobic E. crinita (Roth) J.G. Ag. in the saprobic system of Häyrén (cf. Ray 1974).
(5) Including Häyrén's determinations of E. tubulosa Kütz.
(6) Determined by Häyrén as E. hopkirkii (M'Calla) J.G. Ag.
(7) Includes M. exalbescens Fernald.
(8) Includes Z. pedunculata Reichenb.

(abundance) information from a sample or a locality is called the "sample saprobic index" "S". Detailed processing of the indices is described by Viitasalo (1984). Experience from the Helsinki studies has shown that the sample saprobic index can provide a good contribution to the classification of vegetation samples. In other words, the strict plant sociology of Häyrén is completed by the old concept of individual plant reactions of Kolkwitz & Marsson (1902).

Plant communities react to ecological factors both by taxonomical (genetic) and morphological (physiologic) changes. As an example; in the vicinity of a sewage outlet, *Cladophora* may grow to enormous heights - a physiological change - but its genetic content remains unchanged. Thus observations on the macrophyte morphology could yield a vital contribution to the existing parameters of pollution.

c) Saproby vs. eutrophication

Degradable organic matter discharged into the coastal waters forms gradients of decreasing pollution from the point sources. Organisms directly benefiting from substances in the effluents (heterotrophic or mixotrophic species) appear to be the only real saprobic organisms if the concept of saproby is applied in a strict sense. Some organisms thrive in a saprobic environment mainly as a result of secondary processes that provide a suitable environment (e.g. low red-ox potential or H_2S to be used as electron donor). A number of species are probably just able to stand the adverse conditions of the saprobic environment, especially the low oxygen tension, and benefit from reduced competition.

It is difficult, in practical work, to take the various physiological requirements of different organisms into consideration, because they are largely unknown. As a result, the saprobic classification of organisms is mainly empirical.

Theoretical difficulties arise in the zones of lowest saproby. A number of species which are absent from the most strongly polluted localities increase in abundance in less severely affected areas. These are not saprobic indicators in the proper sense, but rather indicators of eutrophy, i.e. they are species that require high nutrient concentrations to be competitive, without gaining any recognizable benefit from organic substances.

To draw lines between the trailing end of saproby and the undisturbed natural state of the Baltic Sea has proven to be problematical. Häyrén's (1921, etc.) katharobic zone as applied to the littoral of the Gulf of Finland does not correspond well with the katharobic zone in the original sense of Kolkwitz & Marsson (1908), who considered only the running waters of springs and mountain brooks that are continuously replenished. Such waters are essentially unsaprobic, devoid of degradable organic substances. In the coastal areas of the Baltic Sea, however, even the least disturbed localities which Häyrén would have considered to be katharobic will, at least at times, have some organic matter that has been produced by pelagic or littoral biota. Strongly saprobic conditions occasionally occur even in undisturbed natural habitats, especially in sheltered bays with decaying vegetation, either autochthonous, allochthonous or both.

If Häyrén's definition of the katharobic zone is accepted, however, as applying to the local conditions, an additional zone must be added between the oligosaprobic zone and the katharobic zone, viz. the eutrophicated zone. This is the zone where the organic load has been fully mineralized, but part of the mineralized nutrients are still recycled within the system, contributing to raised production rates and raised levels of autochthonous organic substances.

It is important to realize that saprobic systems should be applied with utmost caution to areas outside those for which they were developed. Häyrén's saprobic system was originally developed for the brackish waters around Helsinki (Häyrén 1921, 1933, 1937), although he later expanded it to encompass the whole northern coast of the Gulf of Finland (Häyrén 1944, 1945c). In order to make allowance for strong freshwater influence in some of his study areas, Häyrén (1944) had to define a number of saprobic freshwater and oligohaline associations as an addition to his original work in which the influence of low salinity was only hinted at (Häyrén 1921:51-52).

One problem associated with the application of a saprobic system such as Häyrén's over geographically large areas, and particularly in estuarine localities, is that some species seem to react differently to eutrophication/pollution in waters of different salinities. For example, the species of the genus *Enteromorpha* are frequent on unpolluted shores in fully marine areas, although they show a preference for disturbed habitats, and increased abundance in eutrophic habitats. At the entrance to the Gulf of Finland, at a salinity of about 6 o/oo, *Enteromorpha* species are found almost exclusively in eutrophic or saprobic habitats. The species with the least tendency towards saproby, *E. intestinalis*, is the only one still found in any quantity in unpolluted localities, and then mainly in places with some natural eutrophication, such as coves with stones and boulders, the shores of islands with colonies of nesting sea-birds, or low-lying rock-pools without competition from other species. At even lower salinities, inwards in the Gulf of Finland, and in the Gulf of Bothnia, the occurrence of all *Enteromorpha* species becomes even more dependent on pollution.

Fucus vesiculosus was considered a katharobic species by Häyrén and subsequent authors working on the Finnish coast of the Gulf of Finland. In the Tvärminne area, the innermost distribution limit is at a locality where the salinity varies between 4 and 2 o/oo (Luther 1951b:50). The locality is slightly affected by effluents from the town of Tammisaari. In the Gulf of Bothnia the northern distribution limit of attached *Fucus* is at the summer surface isohaline of 4 o/oo (Pekkari 1973). North of this limit *Fucus vesiculosus* has been found only in one locality, in abundance at the mouth of a sewer outside the town of Raahe, in salinities below 3 o/oo.

4. MACROPHYTE VEGETATION INDICATING CHANGES IN THE STATUS OF THE OPEN SEA AREA

In the outer archipelago zone, far away from the influence of waste water, changes in the macrophyte vegetation have been observed during the last decades (Kangas et al. 1982, Hällfors et al. 1984, Kangas & Niemi 1985, Kangas 1987). The decline and recovery of the bladder-wrack, *Fucus vesiculosus* in semi-exposed localities in the outer archipelago zone have been connected with hydrographic changes in the Baltic proper, i.e. with an increase in salinity and nutrients.

The decline of the bladder-wrack seems to be a result of a negative influence of several integrated environmental factors. The increase in filamentous and periphytic algae has caused a strong increase in the crustacean population in the *Fucus*-biome. In addition to shading and competition for nutrients by the increased amounts of periphytic algae, the grazing pressure has also been directed at the bladder-wrack. Furthermore, increased sedimentation of organic material has prevented its zygotes from germinating on hard substrates (Kangas et al. 1983).

Similar changes in bladder-wrack have been observed in places along the Swedish coast, but no observations of a decline have been reported from the southern part of the Gulf of Finland (Kukk et al. 1985). Thus the connection between large-scale changes in the Baltic Sea and in the phytobenthos is not quite clear. Some local recovery of bladder-wrack has been observed along the southern coast of Finland (Kangas & Niemi 1985).

Marked changes have also been observed in the sublittoral algal belt (Hällfors et al. 1984) but, owing to the too scanty background material on algal sublittoral communities, it is difficult to explain the causes of the observed changes.

It seems important to follow in detail the fluctuations in the macrophytic vegetation in the outer archipelago zone which, in turn, will mainly mirror changes in the trophic status of the open sea.

The hydrolittoral algal belt of filamentous algae in the outer archipelago zone shows very great year-to-year fluctuations (Laurola 1982). It is difficult to use these hydrolittoral communities for indicating changes in the degree of trophy of the open sea. This depends on the fact that environmental factors, such as fluctuations in the sea level, temperature, grazing pressure and competition for nutrients with phytoplankton (Niemi 1975), seem to regulate the growth of algae in the hydrolittoral. Basic research over long time periods in the outer archipelago waters not directly influenced by discharges from the land, is urgently needed in order to identify the fundamental regulating factors.

5. CONCLUSIONS

A considerable number of studies involving aquatic macrophytes have been made along the Finnish coast of the Gulf of Finland since the beginning of the 20th century. Many of them, however, are mainly concerned with ecological, floristical, morphological or taxonomical details. Research has centered on Helsinki and Tvärminne, and to some extent on the area outside Kymijoki, Helsinki being the only area with a useful historical record. Elsewhere, analyses of the flora and vegetation are few and scattered, and mainly concern vegetation changes caused by pollution centres. Some base-line studies exist in the form of M.Sc. theses in university libraries. They should be analyzed for the usefulness of their contents, and the relevant information should be extracted and made more easily available.

Further research should be channelled along two lines. Firstly there is a need to fill in the blanks, i.e. to thoroughly investigate archipelago areas which have thus far escaped attention. They are still essentially undisturbed; the Inkoo Archipelago, the archipelago outside the bays of Pernaja, the Haapasaari-Tammio area and the archipelago east of Hamina to Virolahti (Fig. 1). Secondly, areas which have been investigated once, in most cases years or decades ago, should be reinvestigated in order to assess what changes have taken place in the intervening time interval.

The influence of pollution and eutrophication on the macrophyte vegetation has mainly been studied in the vicinity of the main pollution centres, using the overlapping concepts of saproby and eutrophy. Experience shows that both classifications can be used simultaneously. In estuarine areas salinity gradients frequently interfere with gradients of eutrophy and saproby, making the interpretation of phyto-sociological data quite difficult. This sector clearly needs more eco-physiological basic research. In particular, the physiological adaptation of macrophytes to low salinities and high nutrient levels is not too well understood.

Many more biomass estimates are needed, as are dynamic measurements of productivity and consumption, in relation to environmental factors, which especially influence the development of the hydrolittoral belt of filamentous algae and the *Fucus* belt. Such measurements, however, are costly, and cannot be expected to be performed as part of routine monitoring. In this respect the much more simply constructed periphyton community looks more promising.

The methods of collecting data have greatly developed since the days before World War II. Motorized transportation, underwater viewing and improved rakes have contributed much, but SCUBA diving has had the greatest impact, especially when considering the sublittoral belt. Permanent sampling plots and profiles have proven to be of great value for monitoring both in disturbed and undisturbed areas. Many more permanent sites should be established.

A number of articles show that the aquatic macrophytes and the vegetation they form are valuable indicators of the trophic status of the brackish coastal waters of the Gulf of Finland. There are even indications that changes in salinity and the trophic status of the open sea are reflected in the structure and dynamics of the whole littoral and sublittoral ecosystem, especially in the macrophyte vegetation of the outer fringe of the archipelago. The abundance fluctuations of most species, however, remain to be explained, especially as regards whether they are connected with a general trend of eutrophication of the Baltic Sea, of whether they are caused by natural hydrographical fluctuations.

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